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SOLDERING

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SOLDERING

A
Self-Instructional Manual

Model EI-3133

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

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Printed in the United States of America

595-1884-01

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INTRODUCTION

It is difficult to overemphasize the importance of good solder connections. Whether you are assembling a new piece of electronic equipment, repairing an existing piece of equipment, or just troubleshooting; soldering plays an important part. A sloppy solder connection can have drastic results on the operation of your equipment. Complete failure or improper operation can result if only **one** connection is defective.

Just consider some of the serious problems that an improper solder connection can create. The quality color TV kit that you have paid hundreds of dollars for can be completely inoperative with just a single bad solder joint. A major space shot can be a complete failure because of a single poorly made solder connection. It might cost human lives, or the loss of a fantastic amount of time, money, and effort. Neither you nor anyone can afford such losses.

If you have never soldered before, take the time now to learn this skill well. If you have soldered before, review the process anyway just to make sure you know the fundamentals. It is wasteful to make poor solder connections when you can make good ones in the same amount of time with no more effort. By perfecting your soldering skill, you can be sure of success in assembling electronic equipment that works. Good soldering will eliminate most of your assembly problems, and also the need for troubleshooting and repair. The lost time, expense, and frustration that you avoid will make it all worthwhile.

HOW TO USE THIS MANUAL

This Manual is presented in a self-instructional format. Unlike most manuals, it requires you to actively take part in the learning process. You will be asked to reason out and recall key points as well as write down your observations and answers to review questions. *By interacting with the material, you will learn it faster, retain it longer, and understand it better.* The practice experiments will further reinforce your practical knowledge of soldering.

Here are the specific steps to take. Check off each one as you complete it.

☐ 1. Read the "Objectives." They give you a quick overview of this course, and tell you exactly what you will know and be able to do when you complete it.

☐ 2. Read the lesson material.

This Manual is written in a programmed instruction format. The material you will learn is presented in brief discussions, called Frames, that are numbered and given in numerical sequence. The program starts at Frame 1.

Read the material in each Frame and answer the accompanying question. This will test your knowledge of the facts given in that Frame. You may be asked to fill in a blank, to complete a sentence, or simply to supply missing words. In some Frames, you will be given a question with several answer choices. Simply choose the correct one.

The correct answer for each blank will always be given at the beginning of the next Frame. Cover this answer until after you answer the question. **Be sure to write in all the answers and information requested.** This may seem unnecessary, but the physical process of writing is actually an important part of the learning process.

In most of the multiple-choice questions, the answer you select will also direct you to some other Frame. Here, you will be told if your answer was right or wrong. You will also be given some additional information about the answer you choose.

The programmed instructions are grouped into several major sections, each covering a specific topic ("What is Soldering ?," "Solder," etc.). At the end of most sections are a set of Review Questions. By writing down the answers, you will automatically reinforce your learning and verify your understanding of the key points in that section. The Review Answers are listed separately after the questions.

You do not have to complete this Manual all at one time. But you should finish at least an entire section during any one of your learning sessions. Stopping in the middle of a programmed sequence will ruin the continuity and reduce the effectiveness of your learning. If you are forced to do this, go back and repeat the entire section again later.

It should not take you more than a few hours to complete this entire program, including the Experiments and the Final Examination.

☐ 3. Perform the Experiments. The parts included with this Manual consist of a printed circuit board, a terminal strip, electronic components, wire, solder, and other items. You will use these to put into practice the soldering skills you learn in the Manual. Follow the directions given in the Experiments.

☐ 4. Read the Summary. This is a brief review of all the important facts you should know.

☐ 5. Take the Final Examination. This will tell you what you know or don't know about the subject. After you answer the questions, check your answers against the correct ones on a following page. You are now ready to try out your new knowledge and skills.

☐ 6. Try to apply the knowledge and practice the skills you have learned as soon as you can. It is one thing to read, listen, and write about a subject, and another to actually use the knowledge and skill you have acquired.

The Experiments allow you to develop your soldering skills, of course, but real proficiency will depend upon your application and practice. You will quickly lose this knowledge and these skills if you do not use them. Practice still makes perfect. Use it or lose it.

This entire learning process is very brief, but efficient. If you wish to review or repeat a section, or the entire program, you can do it quickly. An occasional review will recharge your knowledge and skill. Use the "Glossary — Index" (Page 87) for concise, handy definitions of all the important terms, or to locate more information on a specific topic.

OBJECTIVES

The primary purpose of this Self-Instruction Manual is to teach you how to make good solder connections. But it will also tell you how to select the proper tools and materials, how to care for them, and how to use them to solder and unsolder. All of the objectives you should achieve as a result of completing this Manual are listed below.

The number in parentheses after each objective shows the numbered "Frame" where that particular information is presented in the Manual. These numbers are listed here for your future convenience, in case you want to locate that specific information at some future date.

When you complete the training presented here, you will be able to:

1. State the basic purpose of soldering in electronic equipment. (5)
2. Give the name for the process in which the solder molecules mix in with the molecules of the metal being soldered (6)
3. Tell why the alloy called "solder" is used to join electrical parts. (8)
4. Tell what determines the melting temperature of solder. (15, 16)
5. State the type of solder most commonly used for electronic work. (24, 29, 18)
6. Tell why "flux" is necessary. (26)
7. State why only rosin-core solder is used for electronic work. (28, 29)

8. Select the right type of soldering iron for different kinds of soldering. (32, 33, 34)

9. State the best size of pencil iron to use for soldering on circuit boards. (34, 37)

10. Give the name of the electrical characteristic that tells you how much heat a soldering iron will produce. (34)

11. State the biggest advantage that a soldering gun has to offer you. (41)

12. State the most important disadvantage of a soldering gun. (42)

13. State when you should clean your soldering iron tip. (44)

14. State why you should tin a soldering iron tip. (46)

15. Select the four steps you should take to make a good solder connection. (51)

16. List the causes of cold solder joints. (52)

17. State what a good solder joint should look like. (53)

18. Name three items that you could damage by using a soldering iron with too much heat. (54)

19. List the two most common causes of rosin solder joints. (55)

20. Give the name for the soldering error that sometimes creates an accidental connection between two adjacent circuit board foils. (57)

21. List two ways to avoid solder bridges. (58)

22. List the two desoldering methods that are most often used on the average workbench. (63)

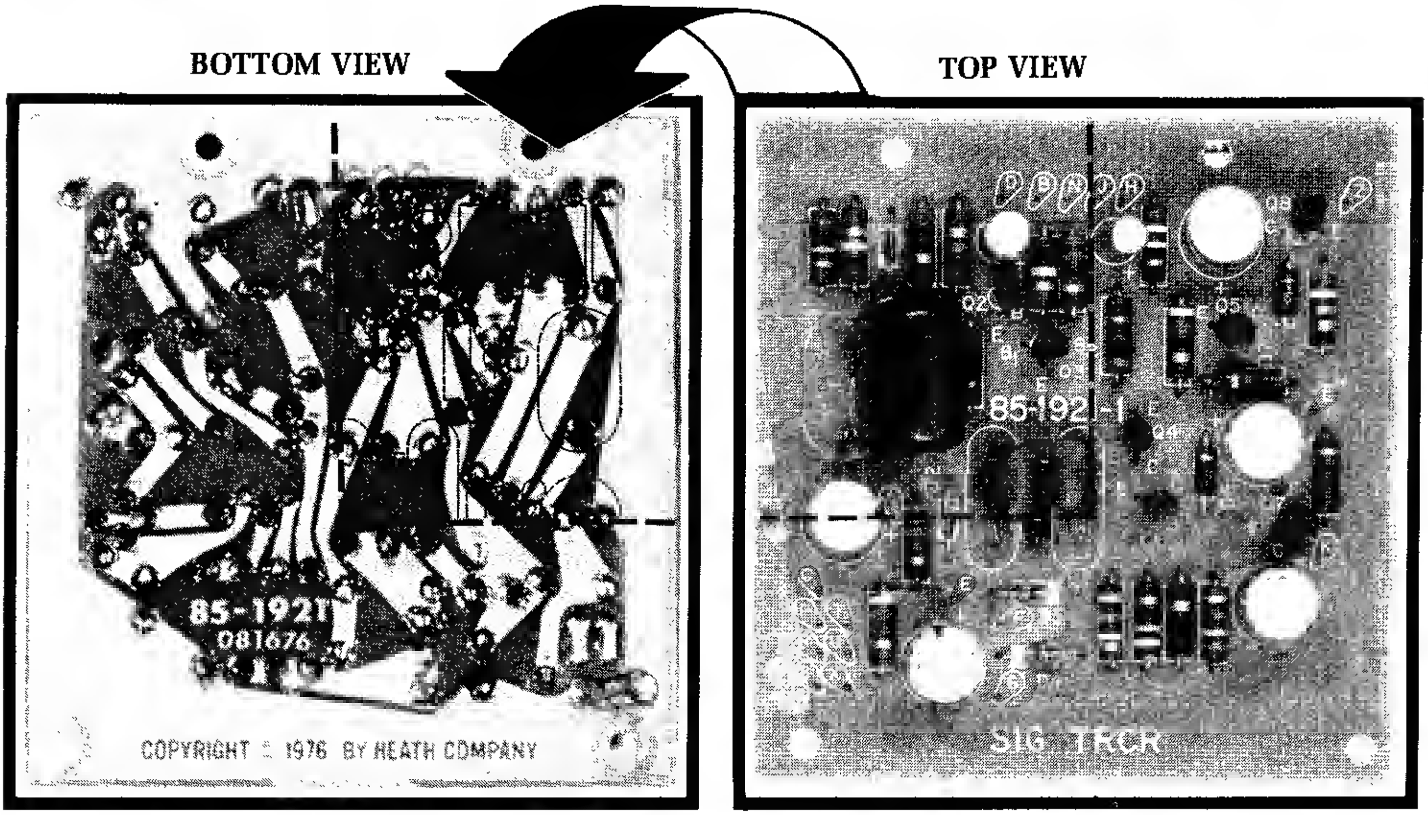


Figure 1A
Typical soldered connections
on a circuit board.

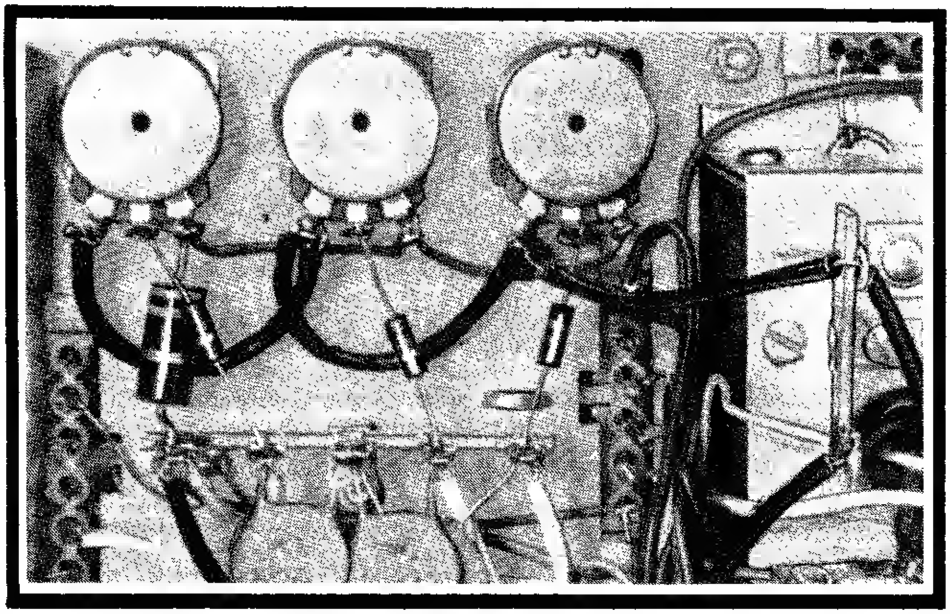


Figure 1B
Typical soldered connections
on controls and on a terminal strip.

SOLDERING THEORY AND TECHNIQUES

What is Soldering?

Electronic equipment is made of many individual electronic components, such as resistors, capacitors, transistors, diodes, integrated circuits, and others. These components are interconnected in various ways to form complete circuits. The circuits are then combined to form a complete functional instrument or system.

Most of these components have wire leads that attach them to other parts. Wire is also used to extend the component leads and make necessary interconnections. The components themselves are mounted on printed circuit boards or terminal strips as shown in Figures 1A and 1B. In both cases, the process of soldering is used to secure the wires because it is the simplest, fastest, least expensive and most reliable method of interconnecting electronic components.

1. Soldering is the process of bonding together two or more metals by applying a tin-lead alloy to them. This tin-lead alloy is called solder. When the solder is heated to a high enough temperature, it becomes a liquid which flows readily onto the component leads or wires to be joined. When the solder cools, it forms an excellent, low-resistance, electrical connection and a very strong physical bond. But unless you use the proper type of solder and apply it correctly, a physically weak and electrically poor connection can result.

Which of the following definitions best describes soldering?

☐ Soldering is the process of bonding together two or more metals by heating them until they become molten and flow into one another .... Go to Frame 2.

☐ Soldering is the process of bonding together two or more metal parts with a tin-lead alloy. .... Go to Frame 3.

☐ Soldering is the process of bonding together two or more metal parts with a glue-like substance called solder that is applied under high heat. .... Go to Frame 4.

2. This answer is incorrect. The process of heating and melting metallic parts until they are molten and flow into one another is known as welding. While some electronic parts and circuits are welded, it is usually a special case. Rarely, if ever, is this process used in assembling most common types of electronic equipment. Go back to Frame 1 and select the correct answer.

3. You're off to a good start. Your answer is correct. Soldering is the process of bonding together (or interconnecting) metal parts by heating them, melting a tin-lead alloy called solder onto them, and letting it harden. As obvious as all of this may be to you as an experienced assembler or a beginner, it is very important to know exactly what soldering is. Let's not take anything for granted here at the beginning. Now go to Frame 5.

4. This answer is incorrect. Electronic parts are never "glued" together. Glue or any type of adhesive is usually an insulator. A good metallic conductor like solder is required to produce a low-resistance, electrical connection. Go back to Frame 1 and select the correct answer.

5. *The basic purpose of soldering, in electronics, is to provide a good electrical connection that is also strong physically.* Each time you make a connection, the tin-lead alloy is heated to its melting point and flowed over the items to be interconnected. The solder molecules then mix with the molecules of the metals being joined at their surface. When the solder cools and hardens, it forms a physically strong, low-resistance, electrical connection.

The solder itself is a low-resistance, metallic substance that melts at a relatively low temperature and adheres well to most types of metal (copper, steel, brass, etc.). When it cools and hardens, it forms an excellent, low-resistance, electrical bond. Electrons (current) flow readily through a solder joint with virtually no resistance.

To fulfill the basic purpose of soldering, a good solder connection must provide a ________ ____________ ______________ and be ____________ ________________.

6. (good electrical connection, strong physically) When the solder melts, it becomes a liquid that flows over the component leads, terminals, or printed circuit conductors. Then it cools and hardens. It effectively fuses the component leads to the terminal or other conductor, forming a solid mechanical structure. The connection is not only good electrically, it is also strong physically.

In any properly made connection, the molecules of the solder actually mix with those of the metal being soldered. This is called "wetting." The solder actually imbeds itself into the surface of the metal. Refer to Figure 2. The shaded area called the "interface" shows that, when wetting occurs, the solder molecules combine with those of the wire lead and the terminal at the surface to form a firm mechanical bond.

In many applications, components are simply suspended between terminals with the soldered leads providing all of the mechanical strength. When a component is attached to a printed circuit board, the board itself provides a good measure of the mechanical stability since the component generally is mounted flat on the board. But it is the soldered connections that hold the component tightly against the board.

__________ is the name of the process in which the solder molecules mix in with the molecules of the metal being soldered.

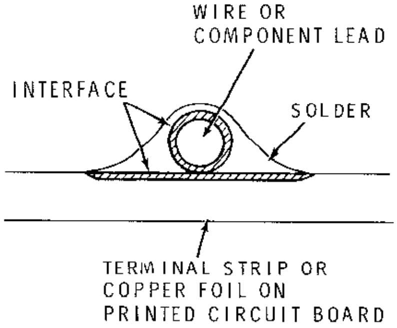


Figure 2
Solder wets the metals being joined, forming an interface where the solder literally imbeds itself into the metals.

7. (wetting) It is the wetting process that actually provides the physical strength and makes the good electrical connection. This makes soldering the best way there is to join electronic parts. It is the fastest, easiest, least expensive, most commonly used, most reliable, and most generally satisfactory method for interconnecting electronic parts.

We hope that we have not insulted you by seeming to belabor the obvious. However, just knowing the importance of something as simple as a solder connection can give you the right attitude about making good ones. Now let's get to the real nitty gritty of soldering. First, the solder. Go to Frame 8.

Solder

8. Solder is an alloy, a mixture of two or more different elements. Solder itself is a combination of two metals, tin and lead. Both of these metals melt at rather low temperatures, much lower than most other metals. That's why solder can be used to join other metals so conveniently.

Solder is ideal for joining electrical parts because it ________ at a much lower ________________ than other metals.

9. (melts, temperature) The tin and lead in this alloy can be mixed in different proportions to make solders with different characteristics. For example, the solder may be a mixture of 50% tin and 50% lead. This would be referred to as a 50/50 solder. The first number indicates the percentage of tin in the alloy, and the second indicates the percentage of lead.

What does the indication 60/40 tell about a type of solder?

☐ The solder is an alloy of 60% tin and 40% lead .... Go to Frame 15.

☐ The solder is an alloy of 40% tin and 60% lead .... Go to Frame 19.

☐ The solder is an alloy with either 60% tin or 60% lead .... Go to Frame 22.

10. 370° is incorrect. You read the temperature for a 60/40 mixture. Go back to Frame 16 and determine the melting point for a 40/60 solder mixture.

11. 37/63 is incorrect. Looking at the graph of Figure 3, you should be able to see that the lowest melting point occurs somewhere between the 60/40 and 70/30 ratios, closer to the former. Try to "eyeball," interpolate, or otherwise guess as closely as you can. Return to the bottom of Frame 17 and select the correct answer.

12. The choice, liquid, is not right. Looking at the graph in Figure 3, you will see that 50/50 solder melts at 414°F. At this temperature and above, it is a liquid. The graph also reminds you that the solidification point is 361°F. Therefore, since the temperature was given as 400°F, there is only one choice left. Go back to the bottom of Frame 20 and select it.

13. The answer is incorrect. Acid-core solder is never used in electronics work. It can severely damage most circuits and components. Neither is the 40/60 tin/lead mixture common in electronics work. If you selected this answer, go back to Frame 25 and repeat all the material up to Frame 29.

14. This choice is not correct. At 400°F, 50/50 solder is not a solid. To be solid it must be 361°F or less. Use Figure 3 to determine the proper state by following a horizontal line from the left at the 400°F point until it intersects the 50/50 vertical line. Then note the area you are in. Go back to Frame 20.

15. Your answer is correct. 60/40 solder is 60% tin and 40% lead. The tin percentage is always given first.

Solder can be made in a variety of ways. Its overall characteristics depend heavily on the exact percentage of tin and lead in the mixture. This is particularly true of the temperature at which a given alloy melts. Pure lead melts at a temperature of 621°F (327°C), and pure tin melts at 450°F (232°C). The really peculiar thing about solder is that it melts at a temperature lower than that of either of its two components. This literally permits us to solder tin or lead items without melting them. For example, tin cans are soldered. *The melting temperature of solder depends strictly upon the exact tin/lead ratio.*

The melting temperature of solder is determined by the ______/________ ________

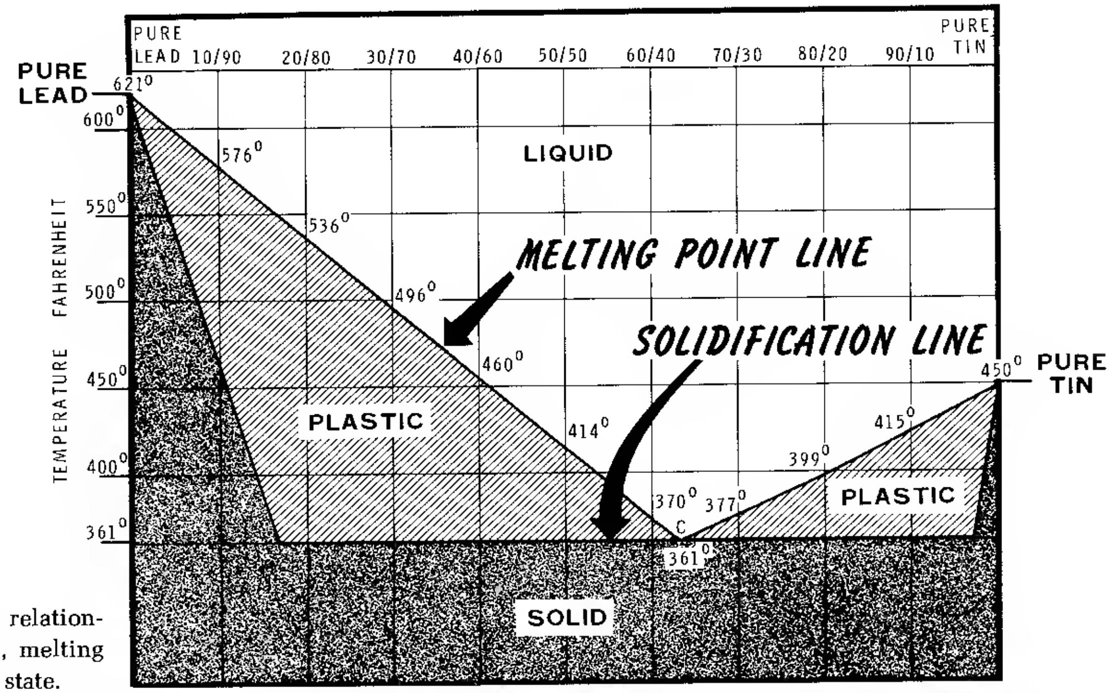


Figure 3
Solder graph, showing the relationship between tin-lead ratio, melting temperature, and solder state.

16. (tin/lead ratio) The temperature of the melting point is a function of the proportions of lead and tin in the solder. The diagram in Figure 3 gives the complete story. This graph shows the melting temperature for all the various tin/lead combinations. The vertical scale is temperature in degrees Fahrenheit (°F).The horizontal scale shows the tin/lead ratio from 100% lead (0/100) to 100% tin (100/0). The major vertical lines indicate the most common tin/lead combinations in 10% increments. The melting point line shows the temperature where the various combinations become a liquid.

To find the melting point of a 50/50 mixture with this diagram, for example, follow the 50/50 line down vertically until it intersects the melting point line. Then read over horizontally to the temperature scale on the left. The melting point of this 50/50 combination is 414°F.

Using the graph in Figure 3, determine the melting point of a 40/60 solder mixture. It is:

☐ 370° .... Go to Frame 10.

☐ 460° .... Go to Frame 20.

☐ 361° .... Go to Frame 23.

17. Right! Good work. 50/50 solder is in the plastic state when it is at a temperature of 400°F. Following a horizontal line over from the 400°F point on the left scale until it intersects the 50/50 vertical line puts you right in the plastic range.

Now take a look at Figure 3 again. Note that, as the ratio of tin to lead increases (from left to right on the graph), the melting point drops. At some specific place, the melting point reaches its minimum value. Then, as the tin content continues to increase, the melting point begins to rise.

Using the graph as a guide, determine at which tin/lead ratio this minimum melting point occurs.

☐ 37/63 .... Go to Frame 11

☐ 63/37 .... Go to Frame 24

☐ 60/40 .... Go to Frame 30

18. Your answer is correct. 60/40 rosin-core wire solder is the most common type used in electronics work. Now let's review the subject of solder; then we will take a look at the tools used to apply it. Go to the "Review Questions" on Page 23.

19. This answer is incorrect. The first number indicates the percent tin, the second number the percent lead. For example, 70/30 solder is 70% tin and 30% lead. Remember, tin first.

Return to Frame 9 and select the correct answer.

20. Very good; 460° is correct. When 40/60 solder reaches 460°, it begins to melt. At temperatures above 460°, the solder is a liquid. This is indicated in Figure 3 by the area marked liquid above the melting point line. At a temperature below 460°, the 40/60 solder is in a plastic state. This is a semi-liquid condition in which the solder can be molded or moved to some degree, but is not liquid enough to actually run or flow. The plastic state is indicated in Figure 3 by the area below the melting point line and above the soldification line. The area below the solidification line indicates the temperatures below which the solder hardens. Note that most solder mixtures solidify at a temperature of 361°F.

Now, just to be sure you understand this, use Figure 3 to determine the state of 50/50 solder when it is at a temperature of 400°F.

☐ Liquid .... Go to Frame 12

☐ Solid .... Go to Frame 14

☐ Plastic .... Go to Frame 17

21. This answer is not correct. It is not fully incorrect, since 63/37 rosin-core solder is used in electronics work, but it is not the most common. Return to Frame 29 and select the correct answer.

22. This answer is incorrect. The numbers given tell the tin/lead percentages in the solder. The first number is tin, the second is lead. The designation 70/30, for example, means 70% tin and 30% lead. As you will see, the characteristics of 70/30 solder are significantly different from 30/70. Remember, tin first. Go back to Frame 9 and try again.

23. 361° is not right. This is the temperature where most solder hardens into a solid. You probably projected the 40/60 line down vertically past the melting point line to the line indicating this temperature. Return to Frame 16 and use the melting point line in Figure 3 to obtain the temperature for 40/60 solder.

24. You are right. Nice going. The minimum melting point occurs with a tin/lead ratio of 63/37. This mixture with the lowest melting point is called the **eutectic** composition. You may hear it referred to as eutectic solder.

You can see from Figure 3 that this type of solder doesn't really have a plastic state. It exists as either a solid or a liquid only. The state change between solid and liquid is sharply defined right at a temperature of 361°F. This is a very desirable solder for electronics work since it melts at a very low temperature and sets or solidifies quickly. This means that you would need only a minimum of heat, thereby reducing the chance of damaging a delicate component or printed circuit board. This solder mixture also cures or cools very quickly, meaning that there is little time for disturbing the connection before it hardens.

Although 63/37 solder is probably best for electronics work, it is not too common since it is a lot more expensive than other mixtures. Instead, *60/40 is the most commonly used grade of solder for electronic work.* It is very nearly eutectic, as you can see from Figure 3, and it has a melting point of 370°, low enough to protect most components during soldering. It hardens quickly too; but as it cools, unlike eutectic solder, it briefly passes through the plastic state. Most of the solder you encounter in electronics will be 60/40.

________ solder is most commonly used for electronic work because it is very nearly ____________.

25. (60/40, eutectic) 60/40 solder is most commonly used because it is close to the eutectic ratio, and it has a low melting point. It also solidifies quickly since it has a very brief plastic state.

To make a solder connection, the usual procedure is to heat the metallic item to be soldered until its temperature is above the melting point of the solder. Then you apply the solder, which melts and flows over the metal piece. When the heat is removed, the solder hardens. This is really the ideal case. In practice, it happens just like this but not without problems. Here's why.

Most metals, because they are exposed to the air, form an insulating oxide layer on their surface. This oxide prevents the solder from wetting and adhering to the metal. In other words, the solder will not flow and stick to the metal piece being heated. It beads up on the connection much like water beads up on the waxed surface of a car. Needless to say, any dirt, grease, wax, paint, or other substance on the metal will also prevent the solder from forming a proper bond.

Solder will not stick to even an apparently clean piece of metal if there is any ________ on its surface.

26. (oxide) The piece of metal, usually a piece of wire, must be clean before solder will adhere to it. Not only must any oxide be removed, but you must also clean off any dirt, grease or other undesirable matter. You could do this by rubbing it lightly with sandpaper, by scraping it with a knife, or by lightly filing it. But fortunately, the solder manufacturers have made this job easier for you. *To remove the most difficult part, the oxide, you use a substance called flux.* This is available as a powder, paste, or liquid which you can use to coat the piece to be soldered.

When the flux is heated, it chemically eats away the oxide and effectively cleans the surface, permitting the solder to flow smoothly and bond securely. A key point to remember is that the flux takes care of the oxide only. It will not remove any dirt or grease that may be present; you would still have to clean this off yourself.

Flux is used to remove the surface ________ from a metal piece before it is soldered.

27. (oxide) Flux removes any oxide from the piece of metal to be soldered. And it works automatically as you heat the connection and apply solder.

It is usually not necessary to use a separate paste or liquid flux, as described above. Most of the solder used in electronics is supplied as a wire with the flux built right into it. See Figure 4.

This kind of solder is actually a type of miniature tubing that contains the flux. The ratio of flux to solder is such that proper cleaning takes place as solder is applied. With this arrangement, the soldering and cleaning both occur almost simultaneously. Note in Figure 4 the several different types of flux cores used by various manufacturers.

Solder is available in several wire sizes. The solder that is used most commonly for general electronic work is about 1/16″ in diameter, while a 1/32″ diameter "thin solder" is used for small delicate work where space is at a minimum.

Most of the solder used in electronics has __________ built into it.

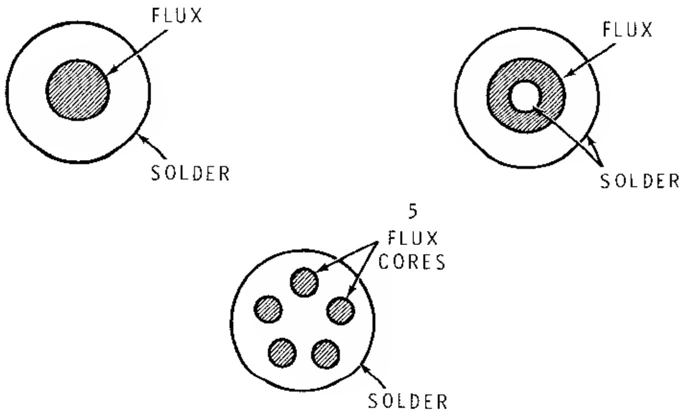


Figure 4
Cross sectional view of wire
solder, showing the flux cores.

28. (flux) Right. The flux is applied automatically when the solder is heated.

Several different types of flux are used for soldering; the two most common types are acid and rosin. Both do a superb job of cleaning the metals and permitting a good electrical and mechanical bond to be formed. However, the acid flux is also highly corrosive. Such a flux is totally unsuitable for electrical and electronic work. Acid core solder is used primarily in metal working.

Rosin-core solder is different. While it is being heated, it is also corrosive; this makes it more effective in removing the oxidation. But as soon as it cools, it becomes noncorrosive. Any rosin flux left on the connection after soldering has no detrimental effect, so there is really no need to clean it off once it dries. But if good looks are important, you can always clean it off with a solvent. On a printed circuit board, for example, the rosin can make the board look unattractive.

You must use __________-__________ solder for electrical and electronic work because, after it cools, it is ____________________.

29. (rosin-core, noncorrosive) *Rosin core solder is the only practical solder for electrical connections.* If you use acid-core solder on a printed circuit board, its corrosive and conductive nature can eat up the components. It can also cause short circuits and undesirable high leakage paths between conductors. In brief, acid-core solder is bad news for electronic work. Do not use any solder for electronic work until you have positively identified its flux type.

Which type of solder is most commonly used in electronic work.

☐ 40/60 Acid core .... Go to Frame 13

☐ 60/40 Rosin core .... Go to Frame 18

☐ 63/37 Rosin core .... Go to Frame 21

30. 60/40 is not correct. It's close, though. Actually, the minimum melting point in Figure 3 occurs with a tin/lead mix between 60/40 and 70/30. Go back and try to interpolate as closely as you can to determine the proper value. Return to the bottom of Frame 17.

REVIEW QUESTIONS

Fill in the blanks below. If you are not sure of the answer to a question, refer back to the correct Frame (see "Objectives," Page 6) and reread it. After you have filled in all the blanks, check your answers against the "Review Answers," which follow.

A. The basic purpose of soldering, in electronics, is to provide a ________ ____________ ________________ that is also ________ ________________.

B. The process in which solder molecules mix in with the molecules of the metal being soldered is called ____________.

C. Solder is ideal for joining electrical parts because it ________ at a ________________ temperature than other metals.

D. The melting temperature of solder is determined by the ______/ ________ ________.

E. Most solder becomes solid at a temperature below ________°F.

F. ________ solder is the most commonly used grade of solder for electronic work.

G. Flux is used to remove surface ____________ from a metal piece before it is soldered.

H. You must use ________-core solder for electrical and electronic work because, after it cools, it is ________________.

REVIEW ANSWERS

A. Good electrical connection, strong physically.

B. Wetting.

C. Melts, lower.

D. Tin/lead ratio.

E. 361°F.

F. 60/40.

G. Oxide.

H. Rosin, noncorrosive.

Go to Frame 31.

Soldering Irons

31. The most commonly used tool for applying solder to an electrical connection is a soldering iron. This tool uses the AC line voltage to heat an element to a temperature somewhat above the melting point of the solder. The element then heats the tip, the part that comes into contact with the connection. See Figure 5.

For best results, the soldering iron tip should be at least 100°F above the melting temperature of the solder. In practice, a minimum temperature of 650°F is desirable for printed circuit board work, while temperatures as high as 1000°F are needed for proper soldering to heavier terminals. Most soldering iron tips have a temperature in this range.

The soldering iron tip should heat up to at least _____ above the solder's melting temperature.

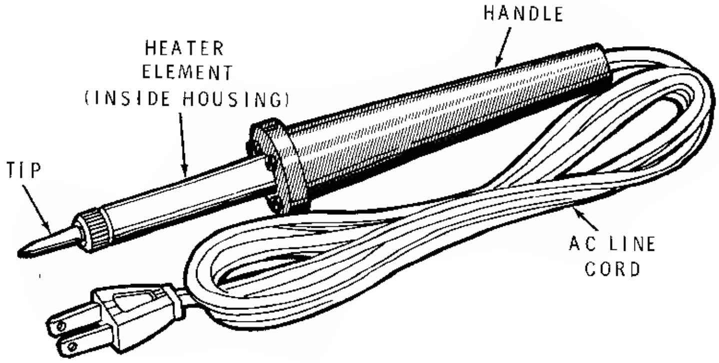


Figure 5
One of the most popular
types of soldering iron.

32. (100°F) Right. Each time you touch a soldering iron to a connection, the connection acts like a "heat sink" and draws heat away from the iron. The amount of heat that is drawn away depends not only on the size of the metal objects to be soldered, but also on such things as common surface area, tip cleanliness, and pressure applied. Therefore, the size of soldering iron that you need for soldering depends on the size of the objects you intend to solder. A small iron may not produce enough heat to melt the solder when you try to solder large wires to a large metal terminal, or to a chassis. And a large iron might damage small, delicate components by heating them too much.

Soldering irons come in a wide variety of sizes, shapes, and types. Small, pencil-size soldering irons are used primarily to solder small and delicate components to printed circuit boards. Larger irons are used for general electronics work and where more heat is required for heavy wires, large connections, and metal work. Soldering guns have the dual advantages of an instant-on, instant-off feature as well as high heat levels. Figure 6 shows a soldering gun and the most popular types of soldering irons. Of course, there are many other sizes and variations.

To solder a large wire to a large metal terminal, you would need a _______ soldering iron.

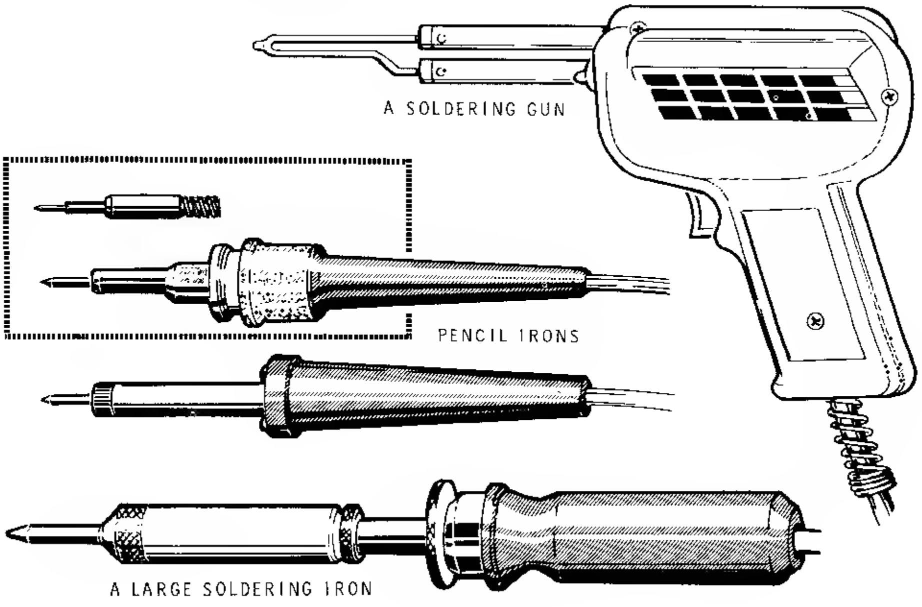


Figure 6
Popular types of soldering irons.

33. (large) The bigger the connection, the more heat it soaks up, and the more it will lower the temperature of the soldering iron tip. If the connection is large and the iron small, it is possible to lower the iron temperature to a point below that at which solder melts. In addition, the larger the connection, the **longer** it takes to raise its temperature to a point where it will melt solder.

All of this is important in selecting the right soldering iron for the required application. If all you are going to do is solder small, delicate, electronic components to printed circuit boards (the most common case), then a pencil iron is almost ideal. It will provide more than adequate heat; and its heat output is not so great that it will damage components or printed circuit boards if you take reasonable care.

On the other hand, this small pencil-type iron may not be adequate to solder larger components or metal pieces. If the metal piece is too large, the iron will never heat it sufficiently to melt the solder (the temperature of the iron will drop to a point where it will not melt solder properly). Obviously, for such cases, a larger iron or soldering gun is needed. The larger the iron, the more heat it generates and therefore the faster it can raise the temperature of a large connection or metal piece to the melting point of solder.

Use a __________ __________ to solder small, delicate, electronic components to a printed circuit board.

34. (pencil iron) Always use a small iron to solder small components to circuit boards. With a larger iron, if you are not careful, you can permanently damage some semiconductors (diodes, transistors, integrated circuits). Most components can withstand high temperatures for no more than about 10 seconds. A good solder connection can be made in only a fraction of this time, but if the heat is far greater than needed, the chance for damage is also greater. Stick to a pencil-type iron for small electronics work.

Printed circuit boards don't take kindly to high temperatures either. They can withstand soldering level temperatures for a short time, but excessive heat can damage them too. Too much heat will cause the copper conductors to literally peel away from the board to which they were bonded. So go easy; use a small iron.

Soldering irons are rated in terms of wattage, an electrical characteristic that tells how much power they will consume. And the amount of heat that a soldering iron will produce is directly proportional to its wattage rating. Soldering irons for electronic and general work have ratings from about 10 watts to 250 watts. The pencil irons for small work fall in the 10 to 50 watt range and are more than adequate for 95% of all electronic jobs. Irons in the 50 to 150 watt range are available for bigger electronic soldering work. The larger soldering irons and guns range from about 150 to 250 watts and are strictly for heavy work. Do not use such irons on printed circuit boards or small electronic parts.

Which of the three soldering irons below is best for soldering transistors and other small parts to a printed circuit board?

☐ 200 watts .... Go to Frame 36

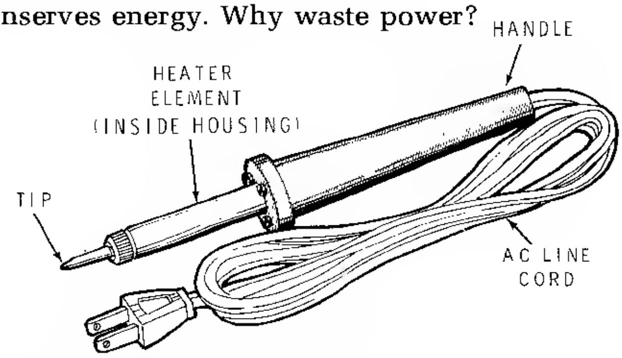
☐ 25-35 watts .... Go to Frame 37

☐ 75 watts .... Go to Frame 38

35. This selection is not right. Of course the heating element is important, but for a given iron size, the tip is the most important part in getting the heat to the solder connection. Return to the bottom of Frame 37 and select the correct answer.

36. This answer, 200 watts, is wrong. Sure, you can get the transistor lead soldered to the board with an iron this big, but you greatly increase the chance of damage to the circuit board and the transistor. Why risk it. Using an iron this big for such a job is like using a sledgehammer on a thumbtack. Return to Frame 34 and select again.

37. (25-35 watts) You are correct. A 25 to 35-watt soldering iron is a perfect size for use on printed circuit boards. In fact, there aren't too many soldering jobs that this small iron won't handle. It will do a beautiful job and will greatly reduce the chance of damage. It also conserves energy. Why waste power?



Most soldering irons consist of four basic parts: the tip, the heating element, the handle, and the cord. The tip is the "business end" of the iron, the part that tránsfers the heat to the connection or piece to be soldered. Usually it is a copper rod that is shaped to a point, and sometimes plated to keep it clean and to minimize the effects of oxidation. Many of these tips are iron-clad and also have a gold or silver plating. This greatly extends the life of the tip and improves heat transfer. Also important is the size of the tip. It can vary from inch-wide tips on large, high-power irons to 1/8-inch wide, sharply pointed tips on low wattage irons used in circuit board work. The tips are usually removable. Figure 7 shows the four basic shapes for soldering iron tips, as well as a typical interchangeable-tip iron. The tip screws into a metal or ceramic housing that contains a wire coil or heater. Electrical current heats the coil, and the heat is transferred through the housing to the tip. Tips usually deteriorate after a period of use, so they are made to by quickly changed. This also permits you to use different shapes and sizes of tips for various applications.

The heating element is mounted to the handle, an insulated body that holds the whole works together. This is the handle you hold to use the iron. The cord connects the heating element to the AC wall outlet.

What part of the soldering iron is the most important in transferring the heat to the connection to be soldered?

☐ The heating element .... Go to Frame 35

☐ The tip .... Go to Frame 39

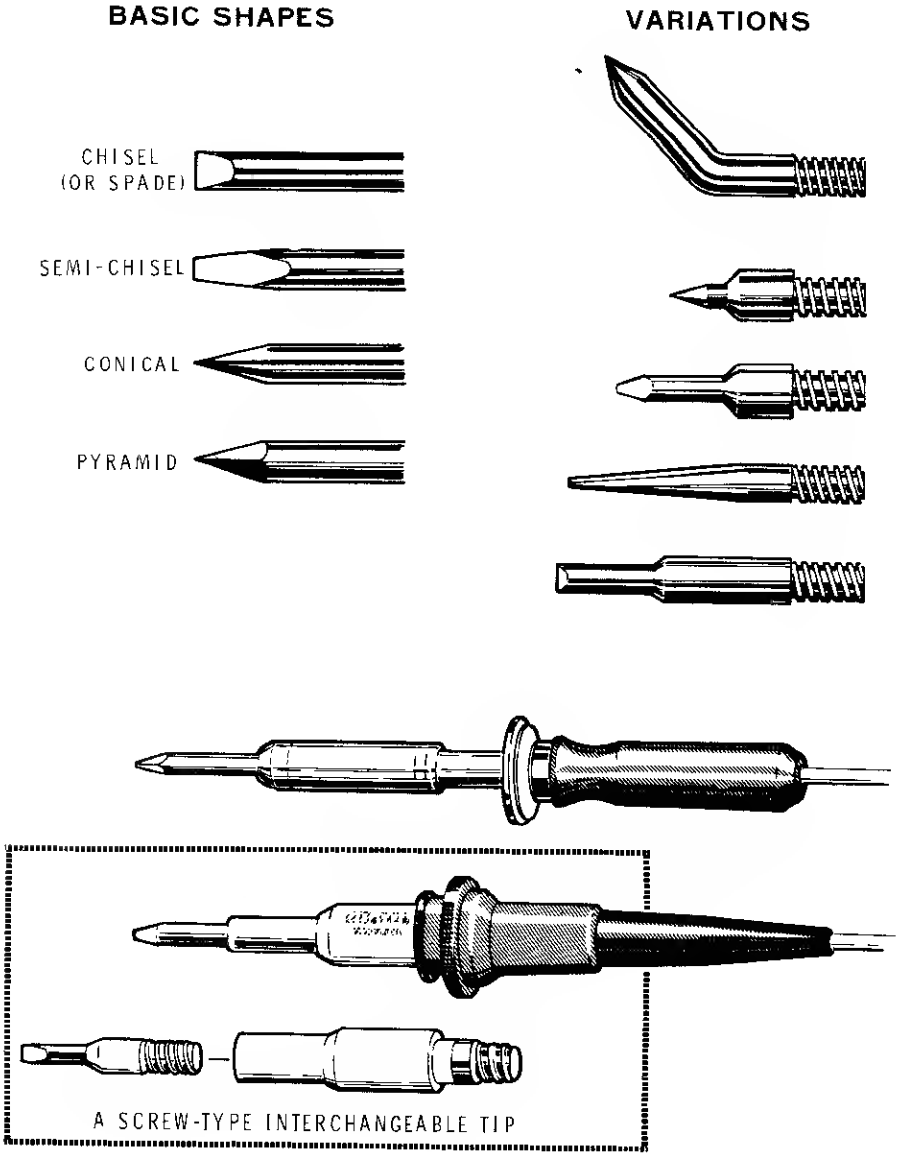


Figure 7
Soldering iron tips, both the large ones and the small ones, may have any of these four basic shapes. Some of the interchangeable-tip variations of these basic shapes are also shown.

38. This answer, 75 watts, is incorrect. A 75-watt iron is a medium range unit that could very well be used to solder transistors to a printed circuit board. With care, it will not cause damage. But it is still far bigger than the job demands. Why waste power. Go back to frame 34 and try again.

39. (the tip) Of course, the tip is by far the most important part of the iron in getting heat to the connection. Since it is the part of the iron that touches the connection, its size, shape and cleanliness are all important. Even the amount of pressure you apply between the tip and the connection and how you position it are important.

Soldering irons come in many different configurations, with many variations and features. The pencil iron is the best for general electronic work, but there are even numerous versions of it. For example, one particular type of pencil iron has interchangeable heating elements as well as tips. The heating element screws into the handle and the tip screws into the element. For heavy work, a high wattage element and large tip can be used. For smaller work, a low wattage element and narrow tip are substituted. See Figure 7.

Another type of iron in common use is the soldering gun. Generally speaking, soldering guns should be avoided for most electronic work. They put our far more heat than the ordinary pencil iron, with typical wattage ratings that are usually over 100 watts. Their tips are also usually much large than those used in pencil irons, so they make the soldering of small circuits difficult.

Would you say that a soldering gun is a good investment for the technician doing a lot of semiconductor component soldering on printed circuit boards? ________

40. (No.) It is not too difficult to damage a component or circuit board even with a small pencil iron. And it's many times easier to damage a component or board with the larger, hotter soldering gun. As far as doing a lot of small electronic work goes, forget the soldering gun and stick to a small pencil iron. But for your general information, let's take a quick look at the soldering gun. A typical unit is shown in Figure 8.

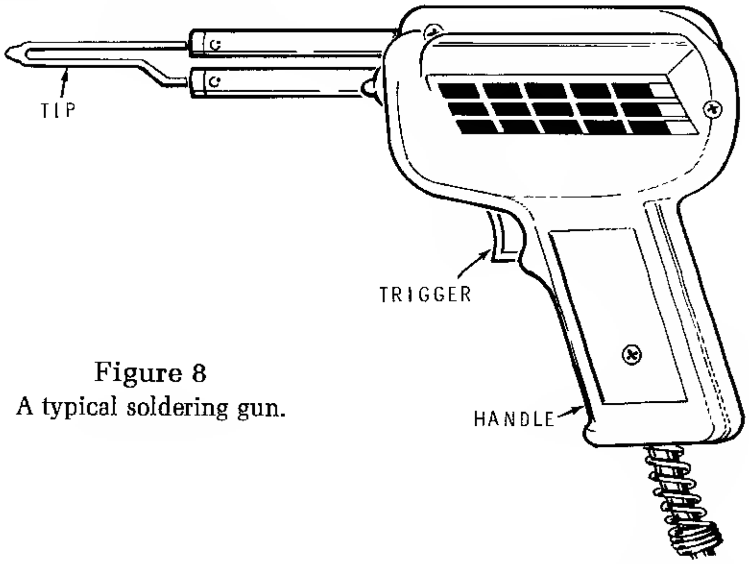


Figure 8
A typical soldering gun.

The soldering gun is so called because of its pistol shape and trigger. Inside it is a transformer that steps down the AC line voltage to a low voltage that is high in current. This high current passes through and heats the tip. The trigger is a switch that turns the power on and off as needed.

To use the gun, you pick it up like a pistol and pull the trigger. Current flows in the tip. Within a few seconds, the tip is hot enough to melt solder. From there on you use it like any other iron. Releasing the trigger removes the current and the tip cools quickly.

Some of the soldering guns that are available are provided with a multiple-position trigger switch that controls the amount of heat produced. A typical gun of this type might have 100-watt and 250-watt trigger positions. A few low-power, small-tipped guns are also available that can be used for small electronic work. But most people seem to have more control with an iron (position pressure, steadiness, etc.) if they hold it like a pencil instead of a gun.

The tip of a soldering gun is heated by the ________ ____________ that passes through it.

41. (high current) Correct! The tip is actually part of the 1-turn secondary winding of the transformer. One of the unique features of a soldering gun is that its tip acts both as a tip and as its own heating element.

The on-off, instant-heat feature is one of the principal advantages of a soldering gun. This lets you have a high-heat soldering tool readily available without wasting power and heat by having a large iron always turned on. This can be especially handy when you need greater heat for an occasional large connection. If you anticipate both large and small soldering jobs, maybe a pencil iron and a gun would both be justified.

Soldering guns also work fine for heavy duty electronic work, like soldering to tube sockets, large terminals and components, and sizeable metal pieces. A gun will do these jobs quickly and without damage. It will solder large heavy work faster, easier, and more effectively than a pencil iron. This is important in large work since a lack of sufficient heat will keep you from making a good connection.

The principal advantages that a soldering gun has to offer is its ____-______, __________ ________ feature.

42. (on-off, instant heat) Right! The on-off, instant heat feature means that the gun doesn't use current continuously, only when you need it for a large connection.

Feel free to use a soldering gun if its advantages will be a help to you, *but be SURE you are also well aware of all its limitations. The most serious one is the very real danger of destroying a small component, like a diode or transistor, on a circuit board.* It can even ruin the circuit board itself by overheating and destroying one of the small circuit board foils. It would be possible to use one on a circuit board, but you would always be taking a chance; a pencil iron is always safer.

Another disadvantage is that you must wait a few seconds for a gun to heat up, whereas a pencil iron is ready to go instantly. It may seem picky to quibble over a few seconds; but when you are soldering hundreds or even thousands of connections, as you frequently do in electronics, turning a gun on and off can be time consuming. Most guns are also pretty heavy because of the internal transformer; usually they weigh three or four times as much as a pencil iron. If you're going to be doing a lot of soldering, a gun can wear you out in a short time.

One more disadvantage that should also be mentioned is that the larger tip on a soldering gun is usually quite awkward for working on small components.

The most serious limitation of a soldering gun is that:

☐ It is too heavy.

☐ The tip is too large for small work.

☐ It has a several-second warmup time each time you use it.

☐ Its high heat level could destroy a small component.

43. (Its high heat could destroy a small component.) The other disadvantages are very real too, of course, but this is the most serious limitation.

In addition to the standard pencil irons and soldering guns, there are also several other types of soldering equipment. Tips with built-in temperature sensing are available, for example, for critical applications. Other units have a feature that cuts their current consumption to just a low idling value when they are not being used. And small, portable, low-power, battery-powered irons are available for remote or field service work. These are handy for emergency repairs where line voltage is not available, but they are usually expensive and short lived (the batteries run down rapidly and need recharging). The AC power line is still your best power source.

Variable-heat pencil irons are also available that have, at the turn of a switch, low-heat positions for circuit board work and high-heat positions for heavier connections. These vary from the all-purpose, three-position model shown in Figure 9 to precision devices with as many as eleven different switch (tip temperature) positions. These variable irons are usually available with several different tip styles.

Variable heat irons can be used for both ________________
________________ work and for ____________________
______________________________.

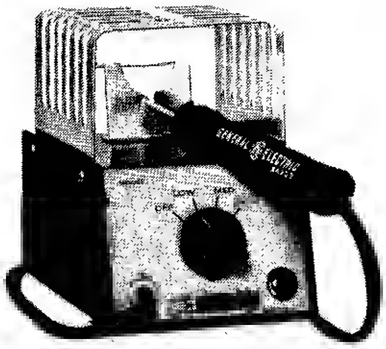


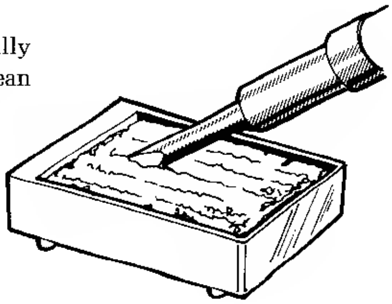
Figure 9
The Heathkit Model GH-17A
variable heat soldering iron.

44. (circuit board, heavier connections) Right. And because of this, this type of pencil iron can be a very useful, all-purpose soldering tool. But don't overlook the "plain Jane" pencil iron; it will handle about 95% of the jobs you run across in electronics and once you have selected an iron for your application, the next step is to learn its proper preparation, care, and use. This includes two very important steps: keeping the tip clean and "tinning" it.

As you use a soldering iron, its tip gets quite dirty quite rapidly because the wax, grease, dirt, and burned flux on the connections all get picked up by the iron. All of this dirt greatly reduces the amount of heat that is transferred from the iron to the connection.

To work effectively, you should quickly clean off the tip practically every time you pick up the iron, just before you use it. Just wipe it off quickly on a clean rag, or wipe it across a small wet sponge. Some iron manufacturers supply a small holder with a sponge in it for just this purpose, like the one shown in Figure 10. If you don't clean the tip frequently, dirt will quickly build up on it and your chances of making a poor solder connection will build up with it.

Figure 10
A wet sponge, like this commercially available model, is often used to clean the tip of a soldering iron.



To make consistently good solder connections, you should clean the tip of your soldering iron:

☐ Only when you first turn it on.

☐ Each time you pick it up to use it.

☐ When you start having trouble getting heat to a connection.

45. (Each time you pick it up to use it.) Only once is definitely not often enough. And an ounce of prevention is still always worth a pound of cure. If you wait till you have trouble getting heat to a connection, you may already have made one or more bad connections.

To say that you should "tin" your soldering iron ("tinning") means that, in order to get the best soldering results, you should thoroughly clean the tip and coat it with a layer of solder. This "tinning" process is used to defend it against that old enemy you read about earlier, oxidation. Not only does this oxidation also occur on the tip, but its formation is accelerated and made worse by the high heat. This oxide layer, if it is not minimized, forms a heat insulator that greatly reduces the transfer of heat from the iron to the connection.

By tinning your soldering iron tip, you create a kind of buffer or interface between the iron and the connection. It minimizes the formation of oxide on the tip. This oxidation can also be reduced somewhat if your iron has a "plated tip," a tip that has an iron or nickel plating on it to increase tip life. But even with a plated tip, it is still a good idea to tin it at regular intervals.

To "tin" a soldering iron tip means to coat it with a layer of ________ to minimize the formation of ________.

46. (solder, oxide) Most tips are made of copper or an alloy of copper. Such tips are good conductors of heat; but when they are heated, a heavy oxide coating forms on them. Tinning an iron means coating the previously cleaned tip with a layer of fresh solder. This protects the tip, minimizes oxidation, and provides an excellent buffer between the iron and the work.

Try to get the solder melted on the tip as soon as possible because oxidation takes place fast. When you turn the iron on, get the tip coated with solder the second it's hot enough. This goes for tinning either a brand new tip or an old one that's just been cleaned. As you tin the tip, wipe the excess solder off periodically with a clean rag; then apply fresh solder. This wiping and coating process gives a good tinning. Just be careful not to burn yourself or the rag as you do this.

If you have a plated tip, new or old, tin it too. A plated tip will stay nicer longer with tinning. Also, it's not good to file a plated tip unless it is unusually bad. Otherwise, you will permanently remove the plating and its benefits. A badly worn and pitted plated tip should just be replaced.

Once the tinning is complete, you are ready to solder.

Always ________ the tip of your soldering iron at regular intervals. This will protect it and minimize oxidation.

47. (tin) Remember: To make good solder connections consistently, tin your soldering iron tip at regular intervals. And make it a habit to clean it off with a rag or wet sponge each time you pick it up. Any tip that has dirt, burned rosin, wax, or grease on it will not work properly.

Figure 11 shows two typical soldering iron holders. These metal trays hold the iron when you are not using it and keep it from burning your workbench. Some holders also have an open frame around them to keep you from accidentally burning yourself or items you are working with.

Now proceed to the "Review Questions."

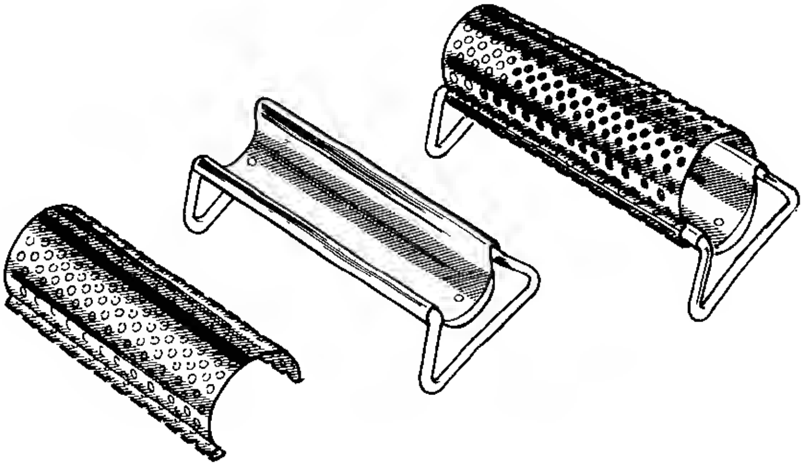


Figure 11
Typical soldering iron holders.

REVIEW QUESTIONS

Fill in the blanks below. If you are not sure of the answer to a question, refer back to the correct Frame (see "Objectives," Page 6) and reread it. After you have filled in all the blanks, check your answers against the "Review Answers," which follow.

A. To solder a large wire to a large metal terminal, you would need a ______________ soldering iron.

B. To solder small electronic components to a printed circuit, you should use a __________________________

C. The ____________ rating is an electrical characteristic that tells you how much heat a soldering iron will produce.

D. To solder transistors onto a circuit board, you should use

a. __________.

1. 200-watt iron.
2. 75-watt iron.
3. 25-35 watt iron.

E. The principal advantage that a soldering gun has to offer is its ______-________, ______________ ____________ feature.

F. State the most serious limitation of a soldering gun.

____

____

G. The best soldering iron for general electronic work is a _____________ type.

H. To make consistently good connections, you should ___________ your soldering iron each time you pick it up to use it.

I. Always _____ the tip of your soldering iron at regular intervals to minimize ___________________.

REVIEW ANSWERS

A. Large.

B. Pencil iron.

C. Wattage.

D. (3.) 25-35 watt iron.

E. On-off, instant heat.

F. Its high heat could destroy a small component.

G. Pencil.

H. Clean.

I. Tin, oxidation.

How to Solder

48. Soldering is really a very simple process — once you get the hang of it. It looks simple and basically it is, but don't be misled. Like many other manual skills, it requires practice before you can really be good at it. The experiments presented later in this Manual will give you some practice. But it will be up to you to obtain additional practice to perfect your work.

As you've already learned, having the proper equipment is the first step. Once you have the correct soldering iron and the proper type of solder, you are ready to go. It is also a good idea to have a wet sponge or clean rag to keep your iron clean. In addition, be sure you have all the other tools you need, such as side cutters, wire strippers, screwdriver and needle-nose pliers.

Before you start soldering, you should remember the basic purpose of soldering in electronics. Which answer below is correct?

Check **one**.

A. ______ To provide a good electrical connection.

B. ______ To provide a connection that is strong physically.

C. ______ Both of the above.

49. (Both of the above.) Soldering bonds together two or more metal conductors to form a good low-resistance, electrical connection **and** a solid mechanical support for the conductors and components. You may be soldering a capacitor lead and a wire to a terminal strip. Or you may be attaching a resistor lead to the copper foil on a printed circuit board. Whatever the case, solder provides both the electrical and mechanical connections.

Before you actually apply solder, it is a good idea to give whatever extra physical strength to the connection you can. For example, instead of just passing the conductor lead through a terminal hole, it is a good idea to bend the lead over or wrap it around the terminal. See Figure 12. By mechanically securing the lead first, you will ensure a more solid physical support. But, perhaps more important, it will keep the lead from moving while the solder is cooling.

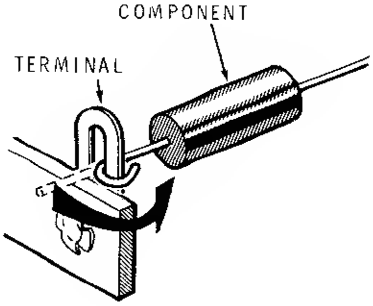


Figure 12
Hooking a component lead around
a terminal to provide physical
support prior to soldering.

After you apply solder and remove the iron, the connection begins to cool. *During this time, the lead must remain still.* If it moves, the solder will not "cure" properly. The connection will not solidify smoothly. It will be weak and may act as high resistance. Such a connection is called a "cold solder joint." You can identify it by its dull, crystalline, or crumbly appearance. Cold solder joints are one of the most common problems in soldering.

During the time that a solder connection is ______________, the leads connected to it must remain ______________.

50. (cooling, still) If any of the leads move when the solder is cooling, the joint will not solidify properly and a "cold" solder joint will result. Avoid this by bending a small hook on the end of the component lead or wire before you attach it to the terminal. Pinch the lead together on the terminal to secure it.

On printed circuit boards, this is usually much less of a problem. Components are always (except for rare exceptions) mounted flat against the board. The leads, which fit tightly in the holes, are then bent over on the other side of the board to hold the component firmly in place. See Figure 13. Soldering then secures the component, and provides additional strength and a good electrical connection.

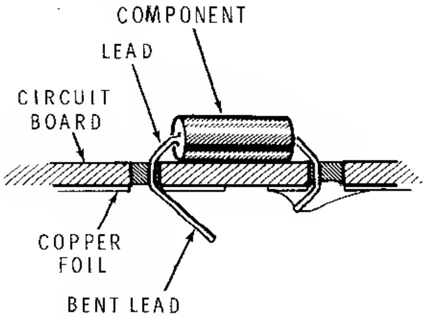


Figure 13
When you mount a part on a circuit board, bend the leads over on the foil side to hold it tightly in place.

Occasionally, there is no convenient means of providing physical support to a component lead that must be soldered. When this occurs, hold the lead absolutely still while the solder hardens. As long as you hold it perfectly still during this hardening period, you can be sure of a good electrical connection. You will also have a good mechanical connection after the solder hardens. See Figure 14.

Unless you are specifically directed otherwise, always mount a component __________ against the circuit board, and __________ the leads on the other side of the board.

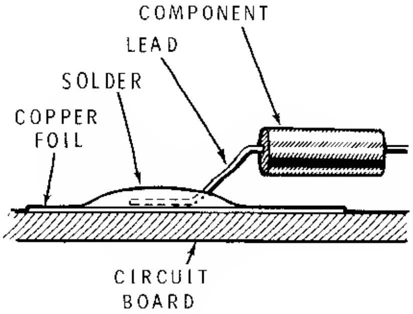


Figure 14
If you MUST solder a lead to a foil, with no physical connection, be sure to hold it absolutely still until the solder hardens.

51. (flat, bend) The actual soldering process is best described in the following four steps. Although they are presented here in a rather lengthy form, for descriptive purposes, each connection is actually made in only a few seconds. These steps are shown in Figure 15, both for terminals and for circuit board applications.

1. Wipe the tip of the iron clean.
2. Place the tip against **both** the lead and the terminal (or foil) at the same time. The idea here is to heat both for two or three seconds before you apply solder.
3. Apply the solder, at the other side of the connection, to the junction point of the lead and terminal (or foil). Let the solder flow over the connection until it is covered. Use just enough solder to cover the connection. Excess solder could make connections that you never intended ("solder bridges") between adjacent terminals or copper foil areas on a circuit board.
4. Leave the tip on the connection only long enough to thoroughly melt the solder, and then remove it. If you don't use enough heat, the solder will not melt completely and you will have a cold solder joint. The solder should have flowed evenly over all leads and parts of the terminal before you removed the iron.

List the four soldering steps below in their proper order.

1.	____	A.	Apply the solder, at the other side of the connection, to the junction point of the lead and terminal (or foil).
2.	____	B.	Leave the tip on the connection only long enough to thoroughly melt the solder.
3.	____	C.	Wipe the tip of the iron clean.
4.	____	D.	Place the tip against both the lead and the terminal (or foil).

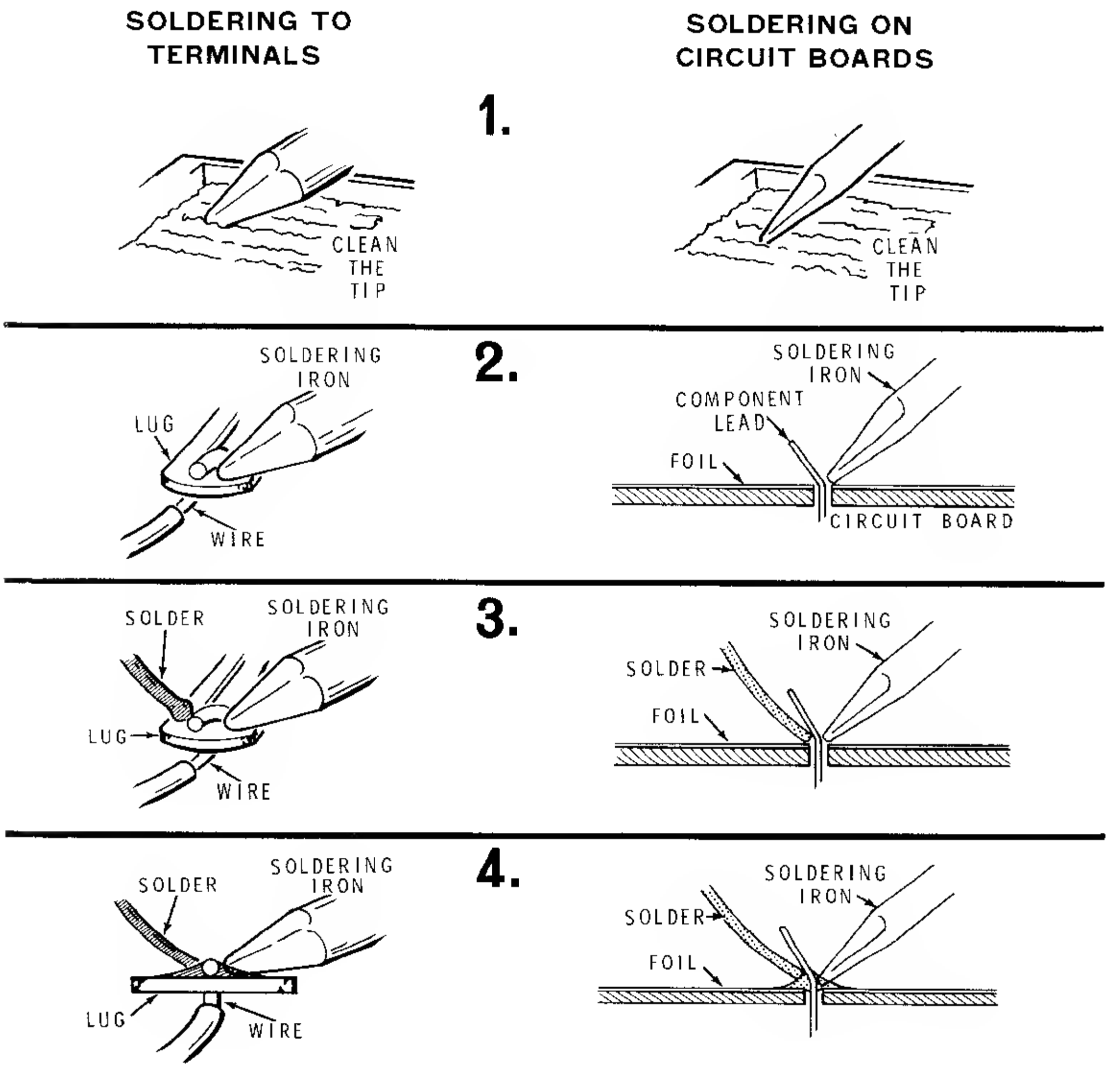


Figure 15
Four basic steps for
soldering a connection.

52. (C, D, A, B) Have a clean tip. And be sure to heat and apply solder to the junction point of the lead and the terminal. Heat this point for two or three seconds first, and then apply the solder. See Figure 16.

It is also very important, after you remove the iron, that you let the solder connection cool properly for several seconds. Even the slightest movement of a lead at this time can cause a "cold solder joint." And don't blow on the connection or touch a wet finger to it to speed up the cooling. Let the solder harden naturally.

GOOD SOLDER CONNECTIONS

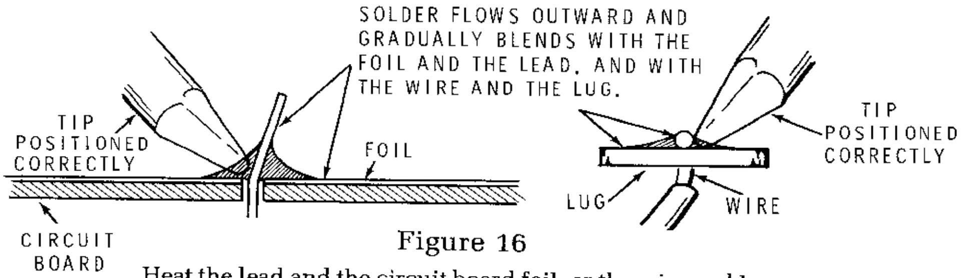

SOLDER FLOWS OUTWARD AND GRADUALLY BLENDS WITH THE FOIL AND THE LEAD, AND WITH THE WIRE AND THE LUG.
TIP POSITIONED CORRECTLY
FOIL
CIRCUIT BOARD
TIP POSITIONED CORRECTLY
LUG
WIRE

Figure 16
Heat the lead and the circuit board foil, or the wire and lug, **at the same time**. This lets the solder flow onto them evenly and make a good electrical connection.

When the connection hardens, take a close look at it. It should look smooth and shiny. If it looks dull, gray, grainy, or crumbly, it's probably a cold solder joint. In this case, reheat the connection, apply a little more solder if necessary, and again let it cool. Then recheck it. Remember the key words, **smooth** and **shiny**. Typical poor solder connections are shown in Figure 17.

Cold solder joints are also caused by insufficient heat. This can occur when the iron is too small or the items to be soldered are too large. In either case, the iron does not supply enough heat to thoroughly melt the solder. It may partially melt, but the lack of heat will prevent the solder from flowing and bonding properly. The solution of course is to use more heat. Either leave the iron on the connection longer or use a larger iron. This will ensure the thorough melting and wetting of the solder. Whatever your solution, just use care to avoid damage to the printed circuit board, terminal or components. Cold solder joints are caused by:

A. ______________________________

B. ______________________________

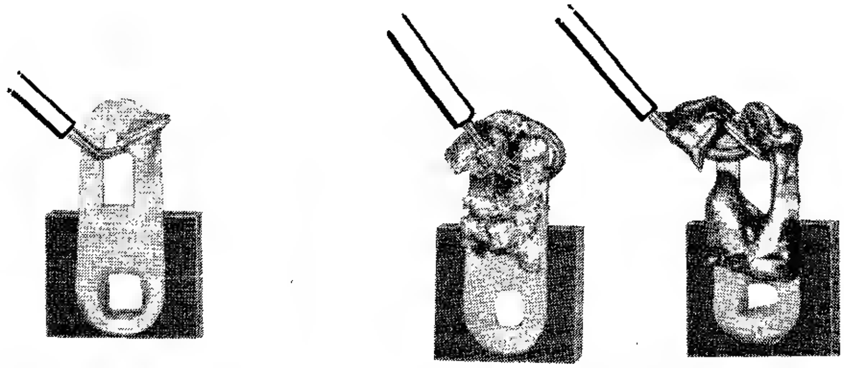
____

53. (movement of a lead during cooling, insufficient heat) Watch out for cold solder joints. They are easy to recognize and readily corrected by reheating. But, you can avoid them altogether by knowing what they are and what causes them.

Now you are well prepared to make good solder connections. The best check for a good connection is its appearance. It should be smooth and shiny. The solder should blend smoothly with the lead and the lug as shown in Figure 17 (also refer to Figure 16). Anything else is subject to suspicion. Don't hesitate to reheat a connection and apply a bit more solder if it looks like one of the poor ones below. It will take only a few seconds and you may save yourself hours of troubleshooting later.

A good solder connection should look ____________ and ____________.

A GOOD SOLDER CONNECTION **POOR SOLDER CONNECTIONS**

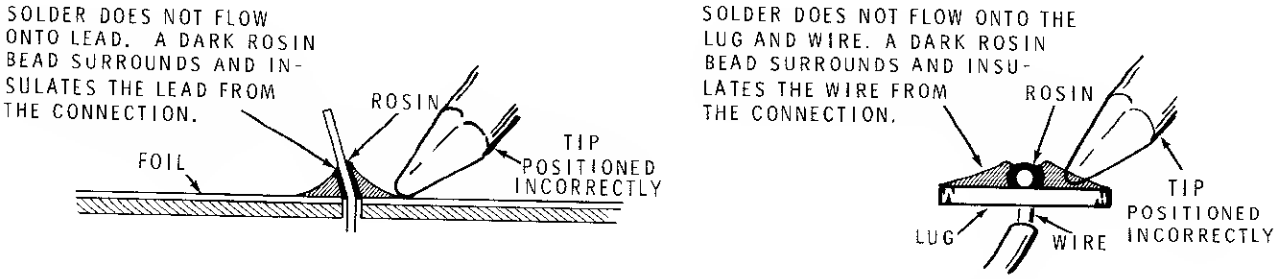


Notice that this connection is smooth and shiny, and that the solder blends smoothly with the terminal.

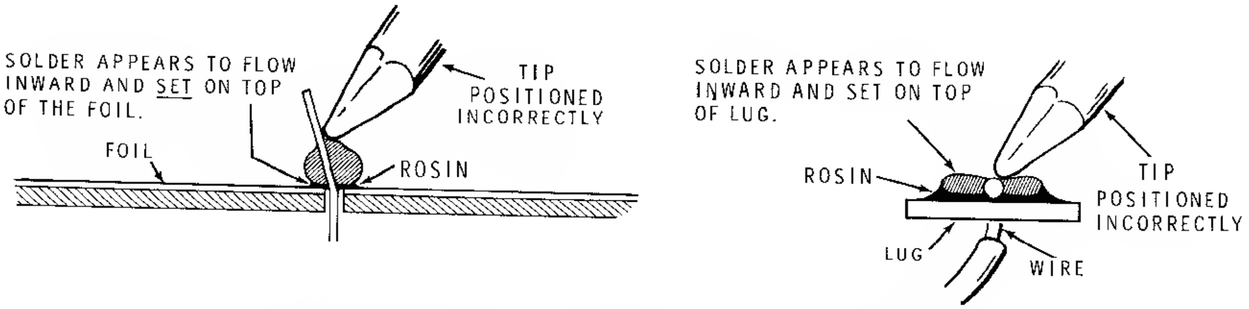
A poor or "cold" solder connection will usually look crystalline and have a grainy texture, or the solder will stand up in a blob and will not adhere to the connection.

Figure 17
Good and poor solder connections.

POOR SOLDER CONNECTIONS


SOLDER DOES NOT FLOW ONTO LEAD. A DARK ROSIN BEAD SURROUNDS AND INSULATES THE LEAD FROM THE CONNECTION.
ROSIN
FOIL
TIP POSITIONED INCORRECTLY
SOLDER DOES NOT FLOW ONTO THE LUG AND WIRE. A DARK ROSIN BEAD SURROUNDS AND INSULATES THE WIRE FROM THE CONNECTION.
ROSIN
TIP POSITIONED INCORRECTLY
LUG
WIRE

When the lead or wire is not heated sufficiently, the solder will not flow onto it, as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder.


SOLDER APPEARS TO FLOW INWARD AND SET ON TOP OF THE FOIL.
TIP POSITIONED INCORRECTLY
FOIL
ROSIN
SOLDER APPEARS TO FLOW INWARD AND SET ON TOP OF LUG.
ROSIN
TIP POSITIONED INCORRECTLY
LUG
WIRE

When the foil or lug is not heated sufficiently, the solder will blob on it, as shown above. To correct, reheat the connection and, if necessary, apply a small amount of additional solder.

Figure 18

54. (smooth and shiny) Remember that while you must apply enough heat to thoroughly melt the solder, you certainly don't want to overdo it and damage a component or connection. Most electronic components are heat sensitive and can be damaged by excessive heat. This is especially true of **semiconductors** (diodes, transistors, integrated circuits, etc.). Most of these devices can withstand soldering temperatures for no more than about 10 seconds before permanent damage occurs. Excessive heat can also burn away the **insulation on wires.** This could expose wires that should be protected. Short circuits could occur. Burned insulation also gives the circuit a sloppy and dirty appearance.

This same precaution about excessive heat also applies to **printed circuit boards.** Too much heat can cause the copper foil to peel away from the board. When this happens, you have ruined what may be a really expensive item and probably the components associated with it. Repair may not be possible. Use just enough heat to ensure a good connection and no more. Each connection should take no more than 3 to 5 seconds at most.

As you can see, soldering is a delicate balance between too much heat and not enough. It's a balance that must, in most cases, be learned by practice. Soldering is a skill that is perfected by plenty of experience.

Name three items that are susceptible to heat damage.

1. ______________________

2. ______________________

3. ______________________

55. (semiconductors, insulation on wires, printed circuit board foils,) Correct! The semiconductors are really easy to destroy with even the smallest of soldering irons. Just by leaving the iron on the connection too long you can ruin these expensive parts. Be careful. On the other hand you don't want to use too little heat and end up with a cold solder joint.

Another problem that can occur if you use too much solder or too little heat is a "rosin joint." As you recall, the rosin helps clean the connection by removing oxidation as it is heated. With a properly soldered connection, the rosin will do its job and most of it will be boiled away. However, if you use too much solder or apply too little heat, a lot of the rosin will remain in the connection. Since rosin is an excellent insulator, it can form a high resistance between items that should be electrically connected. Such connections may appear soldered, but could be an open circuit due to the rosin. Several rosin solder joints are shown in Figure 18 (Page 50).

Most rosin solder joints are caused by:

1. ____________________

2. ____________________

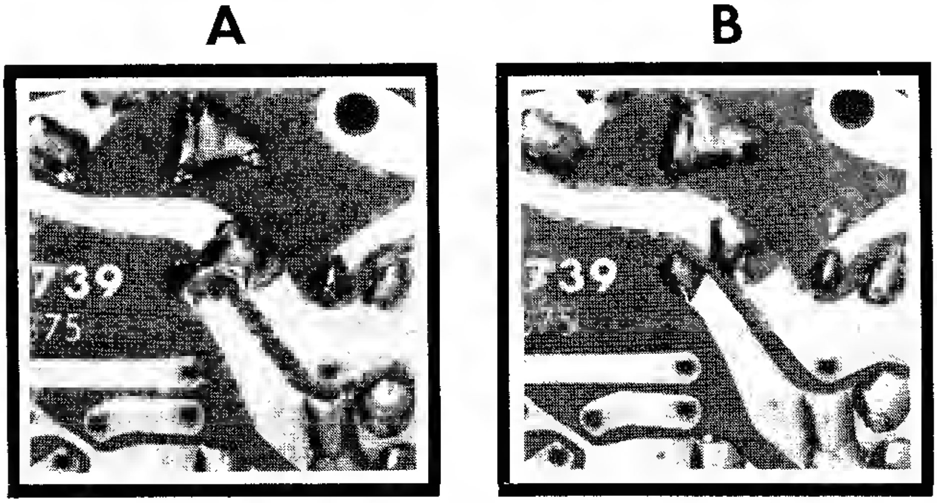


Figure 19
Photograph A shows a solder bridge between two adjacent circuit board foils and Photograph B shows how the connections should look.

56. (too much solder, too little heat) Either of these conditions can produce a rosin solder joint. To avoid them, use the least amount of solder necessary to cover the connection and use enough heat to burn away the rosin. The small wisp of smoke you see rising from a soldered connection is usually caused by the rosin. When the smoke stops, you can be sure the rosin is mostly boiled away.

Now, just as a quick review, list the four soldering steps below in their proper order.

1. ______ A. Place the tip against both the lead and the terminal (or foil).

2. ______ B. Leave the tip on the connection only long enough to thoroughly melt the solder.

3. ______ C. Apply the solder, at the other side of the connection, to the junction point of the lead and terminal (or foil).

4. ______ D. Wipe the tip of the iron clean.

57. (D, A, C, B,) Another problem that frequently occurs during soldering are "solder bridges." These occur when two or more circuit board foils, or adjacent terminals, are accidentally soldered (shorted) together. This is a particularly troublesome problem on printed circuit boards when the foils are small and close together. See Figure 19.

It is quite easy at times to smear solder from one connection to another, especially on the close-together pins of an integrated circuit, for example (see Figure 20). A solder bridge may occur if you accidentally touch an adjacent previously-soldered connection, if you use too much solder, or if you "drag" the tip across other foils or pins as you remove it from a connection. A solder bridge is sure to cause a malfunction and possible damage when power is applied.

An accidental solder connection between two adjacent foils on a circuit board is called a ____________ ____________.

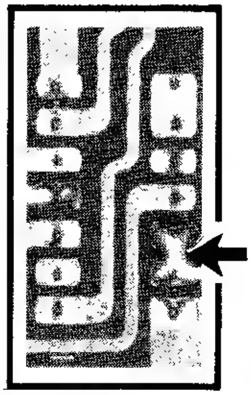


Figure 20
A solder bridge between integrated circuit pins.

58. (solder bridge) To avoid solder bridges, use a small iron tip and thin solder. The small tip helps to eliminate the possibility of it touching two adjacent connections at the same time. The thin solder melts slower and reduces the chance of your using so much solder that the excess will flow to adjacent connections. Always use only enough solder to make a good connection.

If you are careful, solder bridges should not occur. But if they do, correct them immediately. It's a good idea to visually inspect your solder work after you complete it to be sure you have not made any bridges, cold solder joints, rosin joints or the like. A bright light and a magnifying glass are very helpful in checking your work.

If you find a solder bridge on a circuit board, turn the circuit board foil side down and heat the solder between the connections. The excess solder will run onto the tip of the soldering iron, and this will remove the solder bridge.

List two ways to avoid solder bridges.

1. ______________________________

2. ______________________________

(use a small iron tip; use thin solder) Now proceed to the "Review Questions."

REVIEW QUESTIONS

Fill in the blanks below. If you are not sure of the answer to a question, refer back to the correct Frame (see "Objectives," Page 6) and reread it. After you have filled in all the blanks, check your answers against the "Review Answers," which follow.

A. During the time that a solder connection is cooling, the leads connected to it must remain ______.

B. Cold solder joints are caused by:

1. ______________________________

2. ______________________________

C. List the following solder steps in their proper order.

____ Leave the tip on the connection only long enough to thoroughly melt the solder.

____ Apply the solder, at the other side of the connection, to the junction point of the lead and terminal (or foil).

____ Place the tip against both the lead and the terminal (or foil).

____ Wipe the tip of the iron clean.

D. Name three items that are susceptible to heat damage.

____

____

____

E. Good solder joints should look ________ and ________.

F. Most rosin solder joints are caused by ________________ ________ ________ ________________, or ________ ________ ________________.

G. An accidental connection between two adjacent foils on a circuit board is called a ________________ ________________.

H. List two ways to avoid solder bridges.

1. ________________________________

2. ________________________________

REVIEW ANSWERS

A. Still.

B. Movement of a lead.
Insufficient heat.

C. (1) Wipe the tip . . .
(2) Place the tip against . . .
(3) Apply the solder . . .
(4) Leave the tip on . . .

D. Semiconductors, insulation on wires, circuit board foils.

E. Smooth and shiny.

F. Too much solder, or too little heat.

G. Solder bridge.

H. Use a small tip.
Use thin solder.

Unsoldering

59. Occasionally it is necessary to "unsolder" a connection, *to remove the solder from it* and disconnect one or more leads. This could occur, for example, if you had to remove and replace a defective part, or if you had connected a wire to a wrong terminal. In each of these cases, a repair would have to be made. And before you could change the wires or parts, you would have **to remove the solder** from one or more connections. If you were repairing television sets or other electronic equipment, you would probably be unsoldering as many connections as you would be soldering.

The easiest and most obvious way to unsolder a connection is to simply heat it and use long-nose pliers to pull the lead to be removed away from the terminal or copper foil. This simple procedure works quite well in many cases. But it has some disadvantages:

1. The solder is not removed from the connection; it is only melted. Therefore, installing a new or replacement wire or component is difficult because the hole in the connection is still closed by the solder.
2. Melting the solder takes time, so heat could damage the circuit board.
3. Pulling on the leads or wires at the connection could damage the terminal or the printed circuit board.
4. If the wire or lead was initially bent into a hook and crimped, or wrapped on the terminal or connection, it will be difficult to undo this while melting the solder. Again, heat or physical damage could occur.

To properly unsolder a connection with the least problems, you must:

A. ____ Use a lower wattage iron.

B. ____ Remove the solder from it.

C. ____ Clip off the wires or leads with a side cutters.

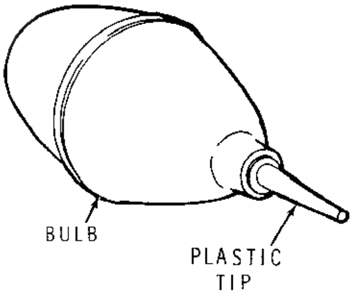


Figure 21
A typical vacuum bulb that you might find on the average technician's workbench.

60. (B — Remove the solder) Correct! To do the quickest and neatest unsoldering job with the least problems or damage, you should remove the solder. All of the solder should be taken off so that you work with the lead to free and remove it. At first this appears to be a problem because of the nature of solder. But with the modern tools and products available, it is quite easy.

One of the most commonly used methods of removing solder is to use a vacuum bulb like the one shown in Figure 21. To use it, you melt the solder with your iron while touching the tip of the bulb to the connection. This tip, usually Teflon,* is not affected by the heat. You squeeze the bulb and then release it when the solder is melted. The bulb slurps up the hot molten solder, removing it from the connection. It may be necessary to repeat this process in order to remove as much of the solder as possible. This process is known as vacuum desoldering because of the vacuum created when you release the bulb.

*DuPont Registered Trademark

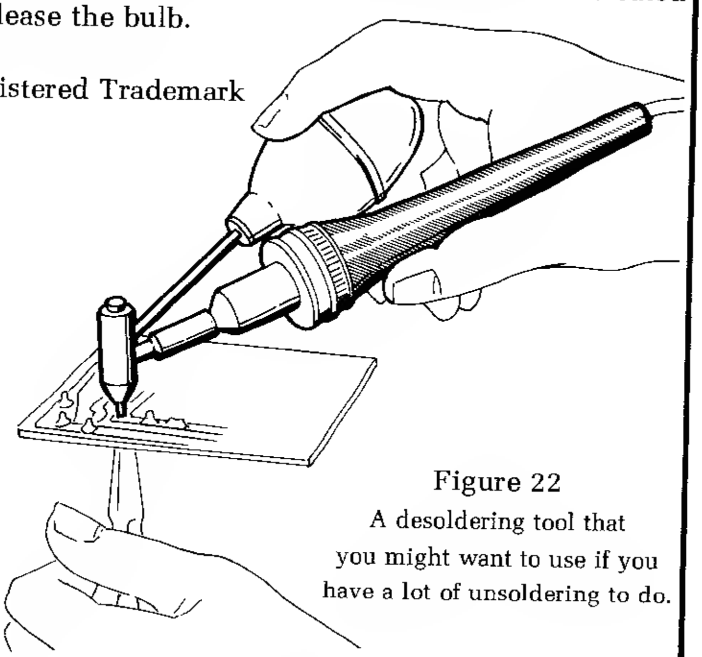


Figure 22
A desoldering tool that you might want to use if you have a lot of unsoldering to do.

If you expect to do a lot of unsoldering, you can use a special vacuum desoldering iron like the one shown in Figure 22. Here the bulb is combined with a special hollow point tip. To use this device, you squeeze the bulb and then touch the tip to the connection. When the solder melts, you release the bulb and the solder is removed.

One of the most commonly used ways to remove solder from a connection is to use a ____________ ____________.

61. (vacuum bulb) Right! When you are unsoldering something with a vacuum bulb, repeat the process until you remove as much of the solder as possible. This will make it easier for you to work with the leads without damage.

A high-vacuum type desoldering tool that is commonly known as a solder sucker is shown in Figure 23. It is larger than the bulb type and has significantly more suction. It is basically a spring-loaded plunger combined with a piston in a cylinder to create the vacuum. To use this device, you cock it by depressing the plunger. Then you melt the solder on the terminal with your iron, apply the tip of the sucker, and push the release button. The spring quickly moves the piston in the cylinder, creating a high vacuum. Outside air pressure then forces the solder into the cylinder. Or, you could say that the tool "pulls" the solder from the connection.

This type of desoldering tool is best for large terminals because of its high vacuum, but of course, it will work on any connection. Even with its extra power it is still a good idea to use it several times to ensure the most complete solder removal.

A high-vacuum desoldering tool that you might want to use for large desoldering jobs, is usually called a ________ ____________.

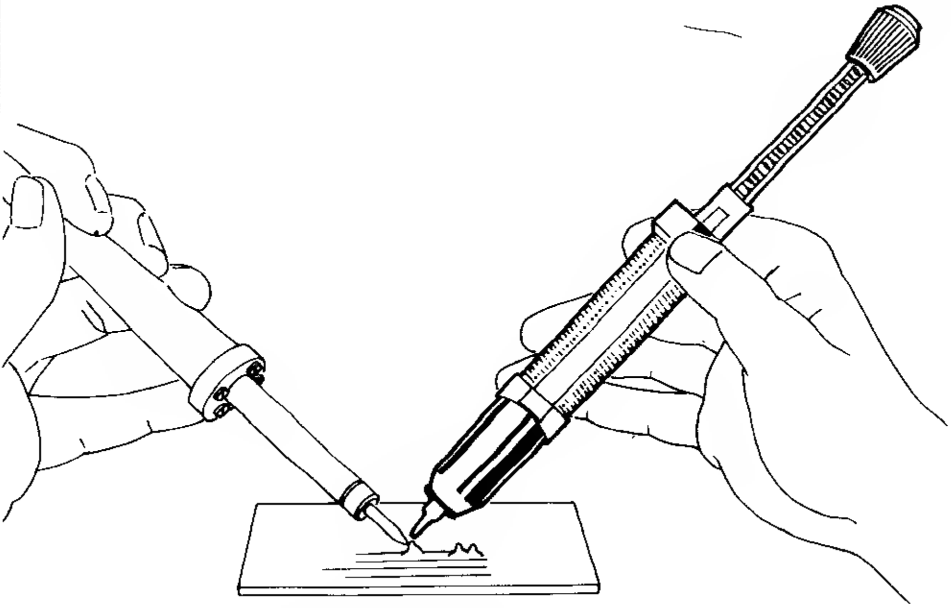


Figure 23

A typical "solder sucker," a high-vacuum desoldering tool.

62. (solder sucker) Flux-coated braid can also be used as a very effective means of removing solder from a connection. This braid is a mesh of fine stranded wire, and when it is coated with a rosin flux, it absorbs solder like a sponge absorbs water.

To use this braid, you place some of it on the connection to be unsoldered. Then you apply the soldering iron, heating the braid and the connection. When the solder melts, the heated flux cleans the braid thoroughly and the solder is drawn up into it. Because of the porous nature of the braid, it will absorb and hold a lot of solder. Then cut off and discard the part of the braid that is filled with solder.

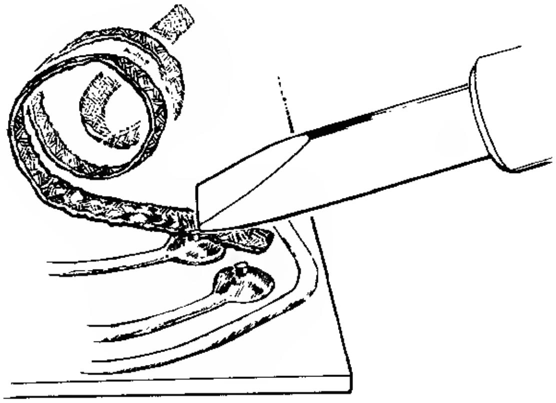


Figure 24
Using flux-coated braid
to remove solder.

Figure 24 shows this braid being used to remove solder from a printed circuit board connection. This is about the cleanest, safest, and most effective desoldering process for printed circuit boards. It is very effective and greatly reduces the chance of damage. As with any technique, it should be repeated as necessary to ensure complete solder removal.

The cleanest, safest, and most effective way to remove solder from a circuit board connection is to use ________ __________ __________.

63. (flux-coated braid) After you remove the solder from the connection, it should be fairly easy to remove the lead or wire with the point of a knife or long-nose pliers. Pry the lead loose gently, breaking away whatever thin layer of solder is left holding it. Be careful here, as you can still cause damage. Reapply the vacuum tool or braid if the lead is still secure, to further remove the solder before you proceed.

Once the lead is removed, replacement is easy since the terminal is clean, the hole is open, and the whole thing has been pretinned by the previous coating of solder. Resoldering will go quickly.

After you remove the solder from a connnection, pry the lead loose ______________.

64. (gently) Now, just to review for a minute.

The easiest way to remove solder from a connection is to simply heat it and then remove the wires with long-nose pliers. But this process can very easily damage some of the parts, or wires, or a circuit board. Therefore, other desoldering methods are generally used. The most common of these methods, the ones that most often are used on the average workbench, use a simple vacuum bulb or flux-coated braid. For a lot of repeated desoldering, you might want to use a bulb combined with a hollow tip iron; and for heavy-duty work, you might prefer to use a solder sucker. And finally, be gentle when you remove the wires so you do not damage anything.

The desoldering methods that are most often used on the average workbench use either:

______________________________________, or

______________________________________.

(a simple vacuum bulb, or flux-coated braid) Now proceed to the "Review Questions."

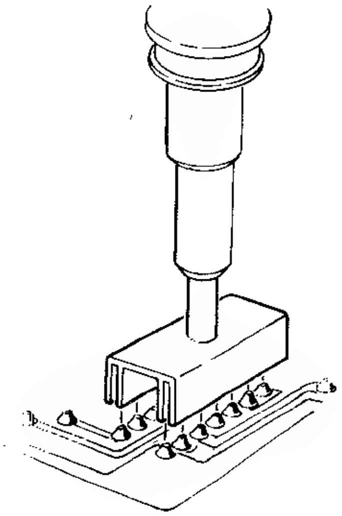


Figure 25

NOTE: Figure 25 shows a special soldering iron tip that is also available for simultaneously melting the solder on all the pins of a dual in-line integrated circuit (like the one shown in Figure 20, on Page 53).

REVIEW QUESTIONS

A. One of the most common ways to unsolder a connection is to use a ________ ________.

B. If you have a lot of unsoldering to do, a special soldering iron is available that has a ________ ________ attached to it.

C. ________-________ ________ is the cleanest and most effective way to remove solder from a circuit board.

D. After the solder is removed from a connection, be sure to pry the lead loose ________.

E. The two desoldering methods most often used on the average workbench are:

____

____

REVIEW ANSWERS

A. Vacuum bulb.

B. Vacuum bulb.

C. Flux-coated braid.

D. Gently.

E. A simple vacuum bulb;
flux-coated braid.

EXPERIMENTS

These experiments will give you some practical experience in soldering. Not only will they show you how to solder to terminal strips and circuit boards, but they will also show you how bad solder connections are made and how to unsolder connections. After you complete this course, be sure to put this new skill to work as soon as you can. Any skill, to be learned well, can only be perfected by a great deal of practice.

Before you proceed to Experiment 1, locate the parts that came with this kit and check them against the following Parts List. Also get your tools together. Be sure that you have:

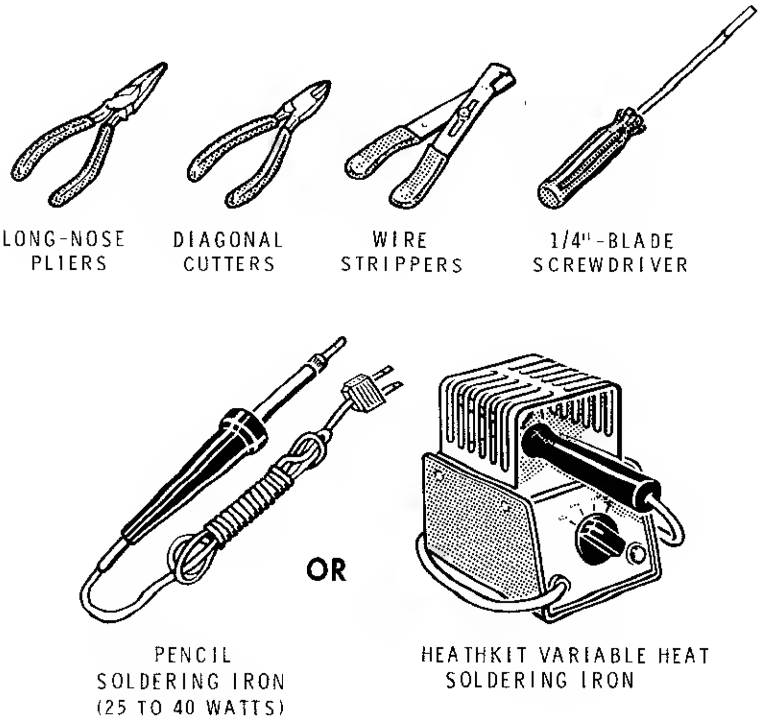

LONG-NOSE PLIERS
DIAGONAL CUTTERS
WIRE STRIPPERS
1/4"-BLADE SCREWDRIVER
OR
PENCIL SOLDERING IRON (25 TO 40 WATTS)
HEATHKIT VARIABLE HEAT SOLDERING IRON

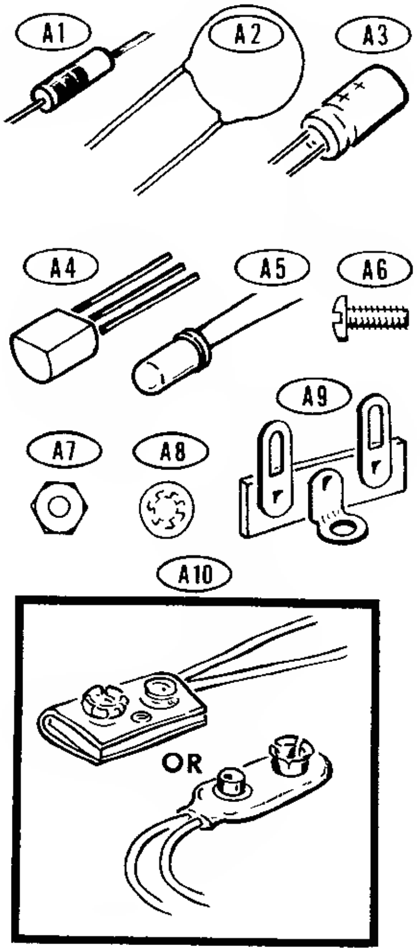
Figure 26

Parts List

NOTE: The "Key" Numbers correspond to the numbers on the Parts Pictorial.

KEY No.	PART No.	QTY.	DESCRIPTION
RESISTORS, 1/2-watt			
A1	1-48	1	390 Ω (orange-white-brown)
A1	1-6	1	470 Ω (yellow-violet-brown)
A1	1-9	3	1000 Ω (brown-black-red)
A1	1-24	2	33 kΩ (orange-orange-orange)
Other Electronic Parts			
A2	21-143	2	.05 μF disc capacitor
A3	25-115	2	10 μF electrolytic capacitor
A4	417-801	2	MPSA20 transistor
A5	412-640	1	LED (light emitting diode)
Miscellaneous			
A6	250-587	1	6-32 × 5/16" screw
A7	252-3	1	6-32 nut
A8	254-1	2	#6 lockwasher
	344-59	33"	White wire
	344-2	6"	Black wire
A9	431-2	1	2-lug terminal strip
A10	432-798	1	Battery connector
	85-1791-1	1	Circuit board
	490-185	1	Soder Wick*
	331-6	1	Solder
	597-260	1	Parts Order Form
	595-1884	1	Soldering, Self-Instructional Manual

PARTS PICTORIAL



To order a replacement part, always include the PART NUMBER. Use the Parts Order Form furnished with the kit. If one is not available, see "Replacement Parts" inside the rear cover of the Manual. Your Warranty is located inside the front cover. For price information, refer to the separate "Heath Parts Price List."

*Registered Trademark, Solder Removal Co.

Experiment 1

OBJECTIVE: Learning how to solder wires to terminals.

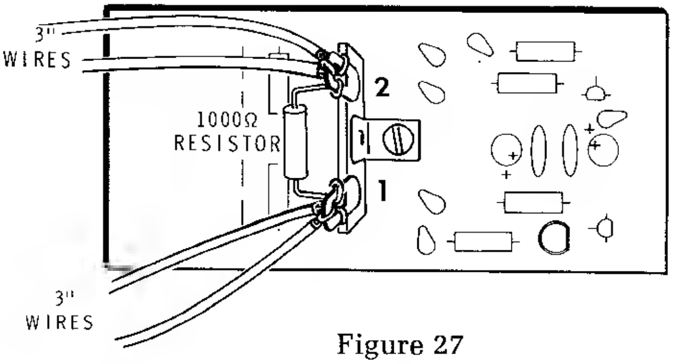
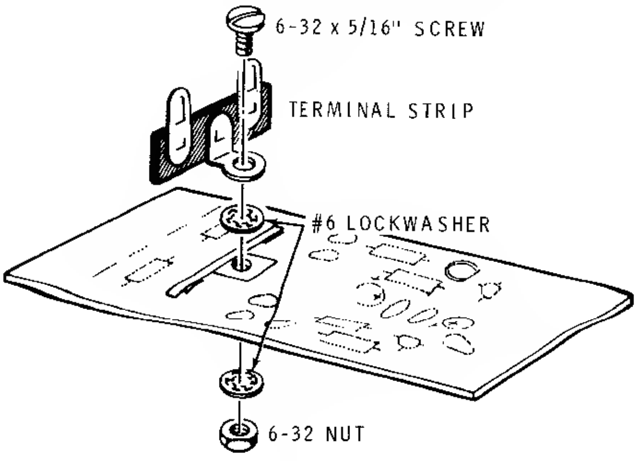
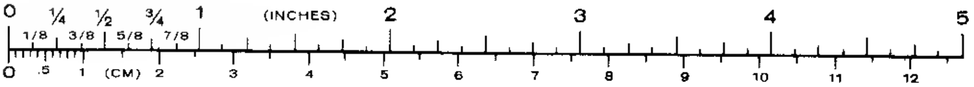


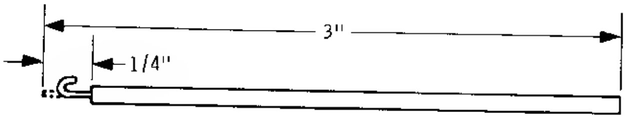
Figure 27

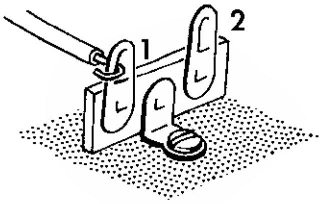
1. Plug in your soldering iron and let it warm up. Then clean and tin the tip.
2. Mount the terminal strip on the lettered side of the circuit board as shown in Detail 27A. Use the 6-32 × 5/6" screw, two #6 lockwashers, and the 6-32 nut.
3. Cut two 3" white wires. (Use the ruler printed below.) Then remove 1/4" of insulation from one end of each wire.



Detail 27A







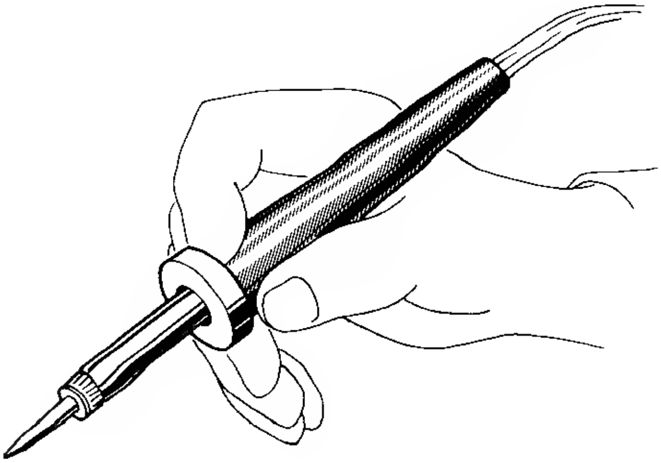
Detail 27B

4. Make a hook on each bare wire end. See Detail 27B.

5. Connect one end of one wire to lug 1 of the terminal strip. Squeeze the loop around one side of the lug.

Before you start to solder connections in the following steps, it would be a good idea to review the four basic steps for good soldering in Frame 51 (Page 46), and to study Figure 15 (Page 47) for the proper way of soldering to terminals. Detail 27C shows you the best way to hold a pencil iron. Each connection should only take 3 or 4 second after you get the "hang of it" and some practice, but it could take longer when you are first learning.

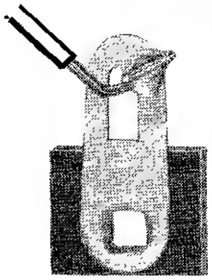
6. Solder the connection.



Detail 27C

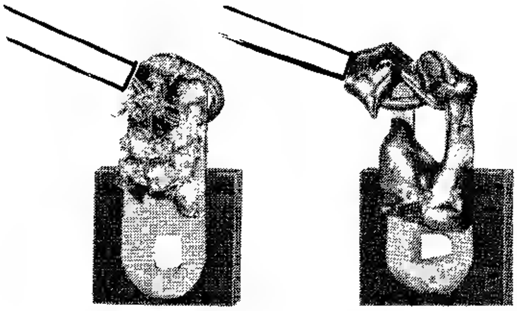
The proper way to hold a pencil iron.

A GOOD SOLDER CONNECTION



Notice that this connection is smooth and shiny, and that the solder blends smoothly with the terminal.

POOR SOLDER CONNECTIONS



A poor or "cold" solder connection will usually look crystalline and have a grainy texture, or the solder will stand up in a blob and will not adhere to the connection.

Figure 28

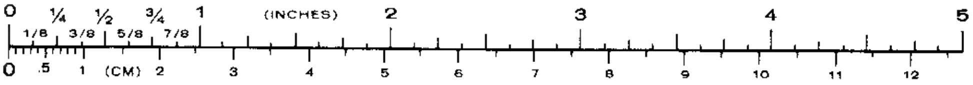
7. Check the connection you just made. It should look smooth and shiny, like the good one shown in Figure 28. It should not look like either of the bad connections.

8. Connect the second wire to lug 1 just above or below the first one. Once again, solder the connection and then check it carefully as you did before. If you find a poor connection, reheat it, if necessary, apply a little more solder.

9. Now cut the black wire into two 3" wires. Then remove 1/4" of insulation from one end of each wire. Note that this wire is not solid, like the white wire, but is made of several strands of smaller wire.

When you use stranded wire, always "tin" each bare wire end by tightly twisting together the separate strands, and then melting a **small** amount of solder on the wire end to hold the strands together. Use just enough solder to hold the strands together. If you use too much solder, the wire end will be hard to bend. (If this occurs, reheat the wire end and then tap it sharply against your work surface to remove the excess solder.)

10. Tin the bared end of each stranded wire.



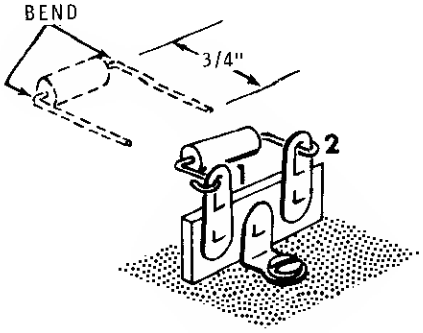


Figure 29

NOTE: The following step will give you some idea of the type of soldering you will usually do at terminals. Always be sure ALL of the wires are properly soldered. It is easy at times to miss a wire when it is partly hidden below other wires.

11. Connect both of these wires to lug 2. Then solder both wires.

12. Be sure **both** of these wires are properly soldered. Be sure the connection is smooth and shiny.

13. Locate one of the 1000 Ω (brown-black-red) resistors and bend its leads with your long-nose pliers as shown in Figure 29. One lead will connect to each lug. Now cut each lead off about 3/4" from the bend (small component leads are often longer than necessary to reach their intended connecting points).

14. Bend a hook in the end of each lead. Then connect one of the leads to lug 2 and solder it.

15. Connect the other resistor lead to lug 1 and solder it. Now check your solder connections again to make sure they are smooth and shiny.

16. This completes Experiment 1. These soldering exercises have given you a practical demonstration of how you solder wires and leads to terminals. If you want additional practice, cut two or three wires and connect them to the terminals.

17. Remove the terminal from the circuit board so it will not be in your way in the Experiments that follow.

Experiment 2

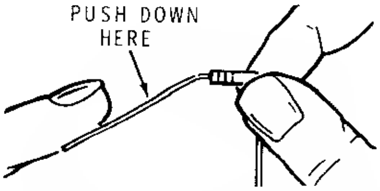
OBJECTIVE: Learning how to mount components on a circuit board.

START

In the following steps, you will be given detailed instructions on how to install and solder a part on a circuit board. Read and perform each step carefully. Use the same procedure whenever you install parts on a circuit board.

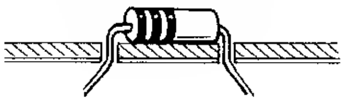
1. Position the circuit board as it is shown, with the printed side (not the foil side) up.

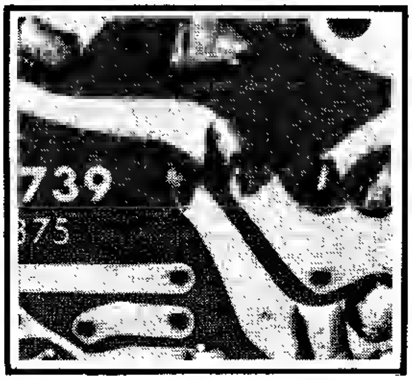
2. Hold a 1000 Ω (brown-black-red) resistor as shown and bend the leads straight down.



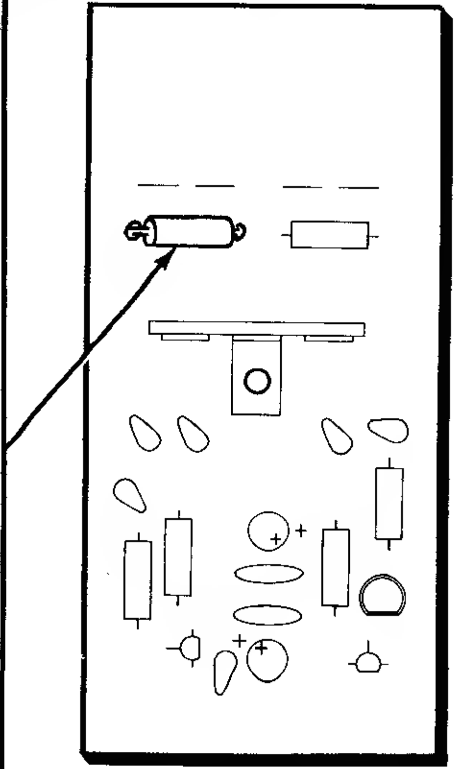
3. Push the leads through the holes at the indicated location on the circuit board. The end with color bands may be positioned either way.

4. Press the resistor against the circuit board. Then bend the leads outward slightly to hold the resistor in place.



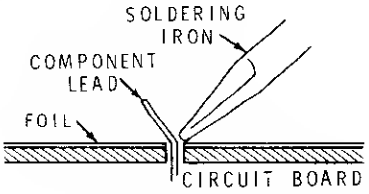


Detail 30A
Good circuit board
solder connections.

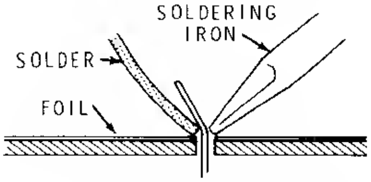


5. Solder the resistor leads to the circuit board as follows:

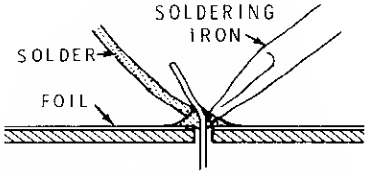
   A. Push the soldering iron tip against both the lead and the circuit board foil. Heat **both** for two or three seconds.



   B. Then apply solder to the other side of the connection. **IMPORTANT**: Let the heated lead and the circuit board foil melt the solder.



   C. As the solder begins to melt, allow it to flow around the connection. Then remove the solder and the iron and let the connection cool.



6. Cut off the excess lead lengths close to the connection. **WARNING**: Clip the leads so the ends will not fly toward your eyes.

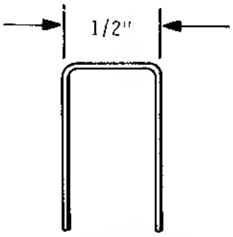
Check the connections. They should look smooth and shiny like the ones in Detail 30A above.

Figure 30

CONTINUE

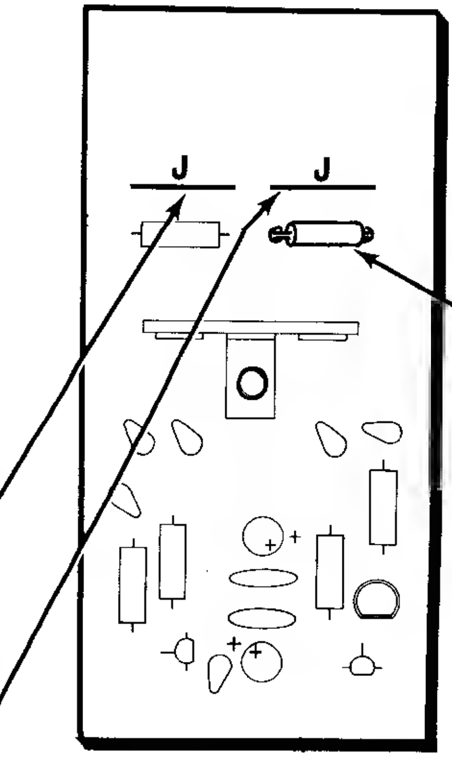
7. Remove all of the insulation from two 2″ lengths of wire.

8. Bend one of these bare wires into a "U" shape as shown below.



9. Install this bare wire at J. Use the same technique that you used to install the resistor. Solder each end and cut off the excess wire lengths.

10. Similarly bend and install the other bare wire. This kind of wire on a circuit board is sometimes called a "jumper" wire, hence the "J" marked on the board. Solder the ends and cut off the excess wire.

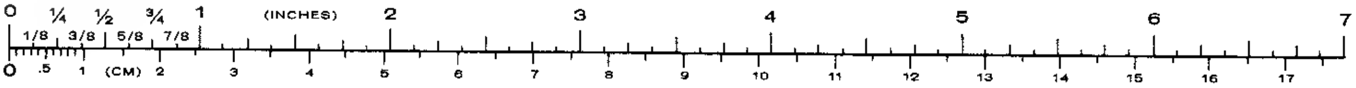


11. Install the remaining 1000 Ω (brown-black-red) resistor. Solder the leads and cut off the excess.

12. Now go back once more and check each of the connections. Be sure they all look smooth and shiny.

This completes Experiment 2.

Figure 31



Experiment 3

OBJECTIVE: Learning to "tack solder."

A "tack soldered" connection is one where a wire or lead does not have any mechanical support. The mechanical strength for the connection is supplied completely by the solder itself. These can be perfectly good solder connections, but it is absolutely essential that you hold the wire still while the solder cools. If you move the wire even a small amount, the connection will probably not be good either mechanically or electrically.

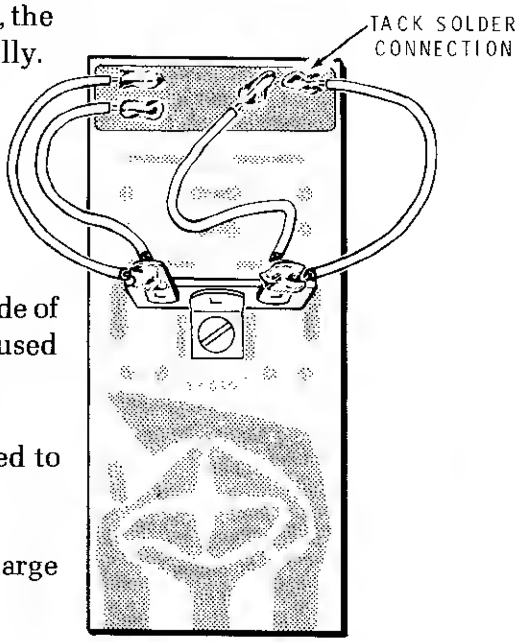


Figure 32

1. Place the circuit board on your work surface as shown.
2. Mount the terminal strip, with the wires attached, on the foil side of the circuit board. Use the screw, lockwashers, and nut you used before.
3. Remove 1/2" of insulation from the end of each wire connected to the terminal strip. Tin the end of each stranded wire.
4. Place one of the stripped wire ends so it lies flat against the large foil. Be sure the insulation does not touch the foil.
5. Very carefully, so you do not move either the circuit board or wire, solder the wire to the foil.
6. Check the connection. If it looks dull, coarse, and crumbly, it is probably a poor connection. Reheat it and, if necessary, add a little more solder.
7. Similarly tack solder two other wire ends to the large foil. Check the connections.
8. Tack solder the remaining wire to the large foil but, this time, move the lead slightly while the solder is cooling. This will show you what a poorly tack-soldered connection looks like.
9. Unsolder each of the wires and lift them from the large foil.
10. Remove the terminal strip from the circuit board.

This completes Experiment 3.

Experiment 4

OBJECTIVE: Demonstrating how you should NOT solder to a circuit board.

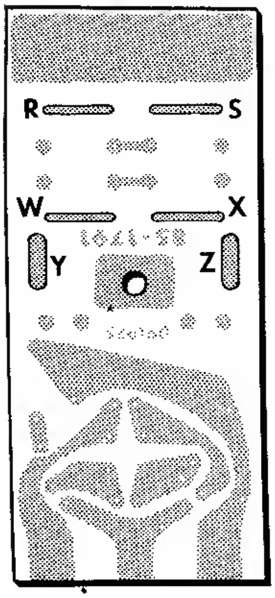


Figure 33

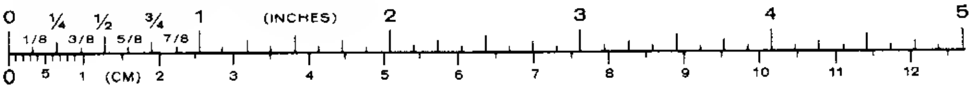
By overheating a circuit board foil, you can make it lift off of the circuit board. How quickly this will occur depends on three things: the temperature at the tip of the iron, how long you hold the tip on the foil, and the quality of the adhesive that holds the foil to the circuit board.

The following steps will give you a practical demonstration for how easily this can occur if you are not careful. Actually, you have plenty of time to make good solder connections on a circuit board, but never hold the tip against the foil for more than just a few seconds.

1. Place the circuit board as it is shown in Figure 33.
2. Firmly place the tip of your iron near one end of foil R. After 10 or 15 seconds, if you move the tip, the foil will begin to lift off of the board. In only a few more seconds, and depending on how hot your iron is, the foil will come completely off the circuit board.
3. Repeat this process again for small foils S, W, and X. Use the second hand of a clock to see approximately how long it takes to lift each foil.
4. Repeat this process again with the two larger foils, Y and Z.

NEVER OVERHEAT THE FOILS ON A CIRCUIT BOARD.

This completes Experiment 4.



Experiment 5

OBJECTIVE: Learning how to unsolder.

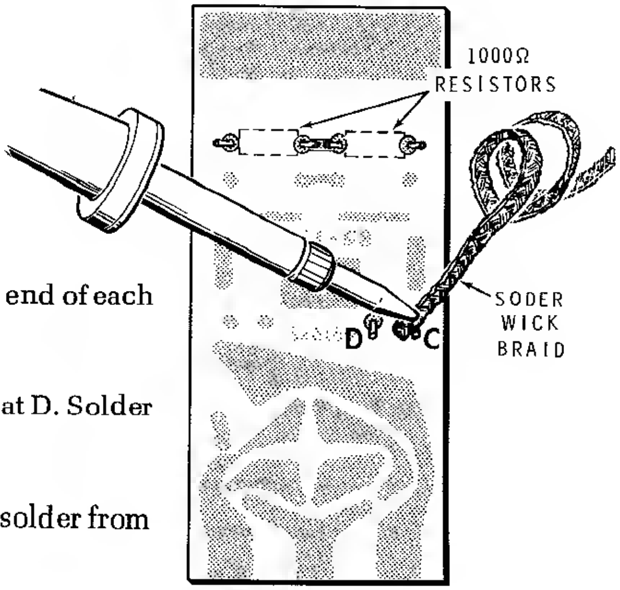


Figure 34

1. Cut two 3″ wires and remove 1/4″ of insulation from one end of each wire.

2. Connect one wire to the circuit board at C and the other at D. Solder both wires to the foils.

3. Now use the Soder Wick braid as follows to remove the solder from the connection at C.

   A. Place the end of the braid over the solder you want to remove.

   B. Place the tip very briefly on top of the braid directly above the solder. The solder will be drawn quickly up into the braid.

   C. Remove the iron and the braid from the foil.

   D. Repeat this process with an unsoldered part of the braid until all of the solder has been removed.

   E. Cut off the solder-filled part of the braid.

4. Remove the wire at C from the circuit board.

5. Similarly remove the solder and then the wire at D.

6. Use the braid to remove the two 1000 Ω resistors from the circuit board.

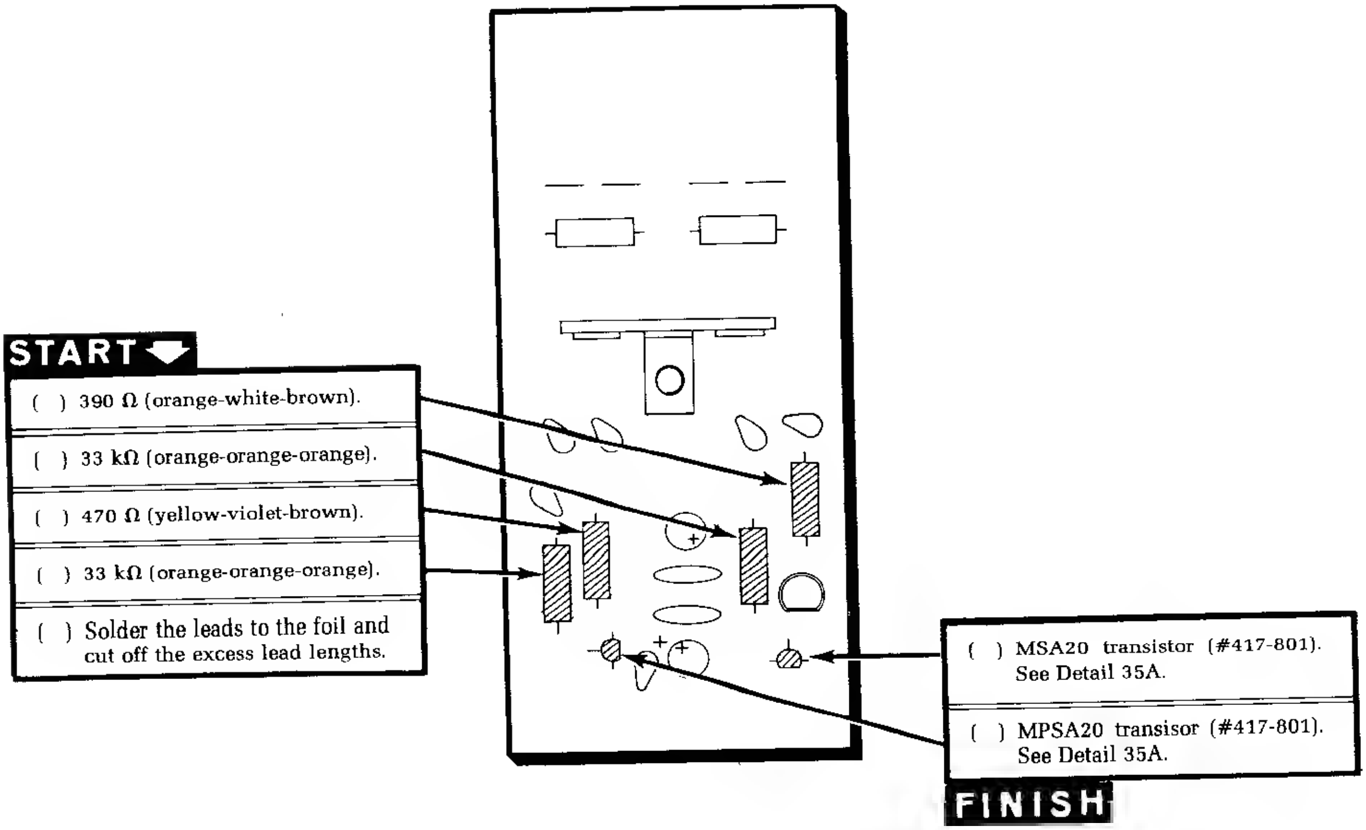
This completes Experiment 5.

Experiment 6

OBJECTIVE: Assembling the test multivibrator circuit.

ASSEMBLY STEPS

Position the circuit board as it is shown in Figure 35. Then complete the steps on Figures 35 and 36. Resistors will be described by their resistance value in ohms (Ω) and color code. Capacitors will be described by their capacitance value in microfarads (μF). Mount components on the circuit board as you were instructed on Page 69.



START

( ) 390 Ω (orange-white-brown).

( ) 33 kΩ (orange-orange-orange).

( ) 470 Ω (yellow-violet-brown).

( ) 33 kΩ (orange-orange-orange).

( ) Solder the leads to the foil and cut off the excess lead lengths.

( ) MSA20 transistor (#417-801). See Detail 35A.

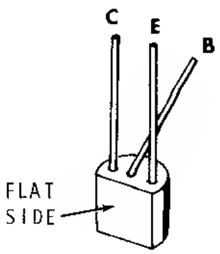
( ) MPSA20 transisor (#417-801). See Detail 35A.

FINISH

Figure 35

Prepare the transistor leads and install each transistor as follows. Follow the steps carefully, since a transistor that is installed incorrectly will not work.

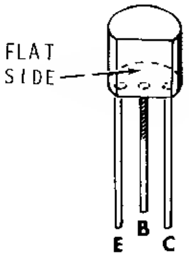
①



Bend the center lead back slightly.

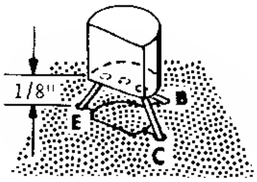
IMPORTANT: Make sure it is bent away from the flat side of the transistor.

②



When the transistor is positioned with the flat side as shown, the leads are identified as E (emitter), B (base), and C (collector). This is very important to note when you install the transistor in the socket.

③



The letters E, B, and C are printed on the circuit board. Insert the center (B) lead of the transistor in hole B and the two end leads in holes E and C respectively. Position the transistor 1/8" above the circuit board. Then solder the leads to the foil and cut off the excess lead lengths.

Detail 35A

START

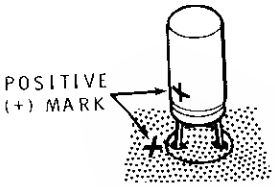
( ) Connect the wires coming from the battery connector as follows. Solder each wire as you connect it.

Red wire to hole B.

Black wire to hole A.

NOTE: If you have a Heathkit Electronic Center nearby, you may want to skip the next three steps. (see "Operation," Page 77) If you do not have a Heathkit Electronic Center nearby, perform these steps.

( ) 10 μF electrolytic. Be sure to match the positive (+) mark on the capacitor to the (+) mark on the circuit board.



( ) 10 μF electrolytic.

( ) Solder the leads to the foil and cut off the excess lead lengths.

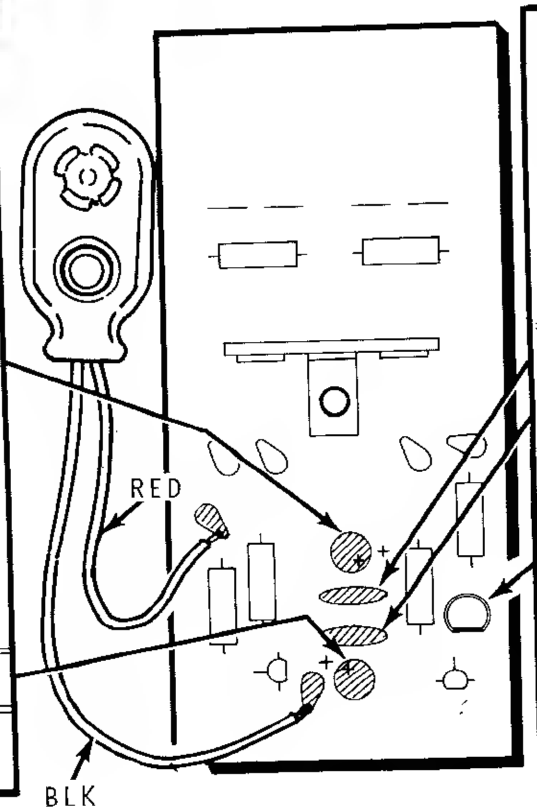
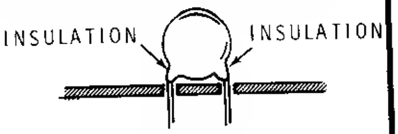


Figure 36

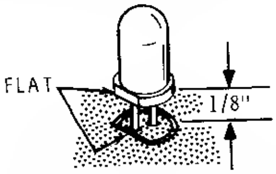
NOTE: When you install disc capacitors, do not push the insulated portion of the leads into the circuit board holes. This could make it difficult to solder the leads to the foil.



( ) .05 μF disc.

( ) .05 μF disc.

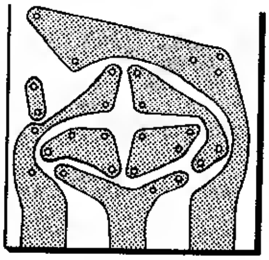
Note the flat on one side of the LED (#412-611). Be sure to position the LED so the flat is over the outline of the flat on the circuit board. Mount the LED 1/8" above the circuit board.



Solder the leads to the foil and cut off the excess lead lengths.

FINISH

Now check the circuit board carefully. Be sure each connection is smooth and shiny. Be sure there are no solder bridges, especially in those areas where separate foils come to each other. Compare the foils against Detail 36A, below. Also refer, if necessary, to the illustration of a solder bridge on Page 52.



Detail 36A

OPERATION

To make sure you have assembled your circuit board properly, you can check it either of the following ways:

1. If you are not near a Heathkit Electronic Center, connect a 9-volt battery to the battery connector. The red LED should blink at a rate of about 1 or 2 times a second. (The two 10 µF electrolytics should be installed.)

2. If you are near a Heathkit Electronic Center, take the completed circuit board there and plug it into their SK-1 test fixture. (The circuit will not operate properly if you installed the two 10 µF capacitors.) If you assembled it properly, the test fixture will light up and produce a buzzing sound. The red LED should be lit continuously.

   If the circuit board does not operate properly, check to be sure each component is installed in the right place, and also be sure each of your solder connections is good.

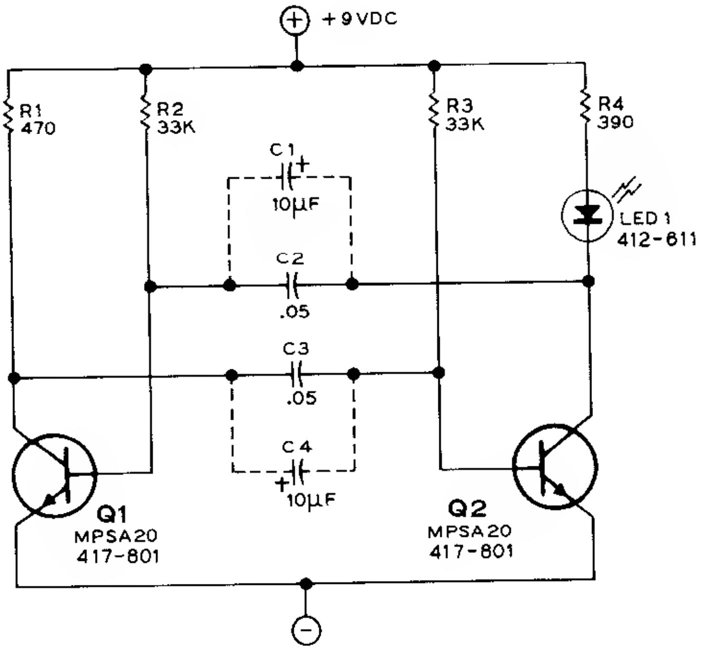


Figure 37

Schematic Diagram of the
Heathkit® Astable Multivibrator, Model EI-3133

The circuit you have just assembled is a multivibrator, a free-running, 2-transistor oscillator. In this circuit, one transistor switches on while the other switches off. This rapid switching action occurs at a rate that is controlled by the values of the resistors and capacitors in the circuit.

THIS COMPLETES THE EXPERIMENT

SUMMARY

NOTE: The small numbers that appear after some of the sentences below refer to the Frame where that information appears in the Manual. Refer back to that Frame if you want to review that information.

Soldering is the process of bonding together two or more metals by heating them, melting a tin-lead alloy called solder onto them, and letting it harden.[1] The basic purpose of soldering, in electronics, is to provide a good electrical connection that is strong physically.[5] The solder molecules actually mix with the molecules of the metals being joined, at their surfaces. This surface-area mixing of the two metals is called "wetting."[6]

A solder alloy with a 60-40 tin-lead mixture is used most commonly for electronic work because it has a very low melting point and it solidifies quickly.[24] But before solder will adhere to a metal, the oxide layer must be removed from the metal's surface by a chemical called "flux".[26] For electronic and electrical work, most of the solder has this flux built right into it.[27] And of the several types available, only rosin-core solder can be used.[28] Use 60-40, rosin-core solder for all your electronic and electrical soldering.

The type of soldering iron you use depends on your application. To solder a large wire to a large metal terminal, for example, you would need a large soldering iron.[32] To solder small electronic components to a circuit board, you should use a pencil iron.[33] Soldering irons are rated in terms of "wattage," an electrical characteristic that tells how much power they will consume. Usually, a 25-35 watt pencil iron is a perfect size for circuit boards, and it will handle most other jobs very well too.[34, 37]

A soldering gun can be another useful soldering tool, but you have to know its advantages and its limitations. Its principal advantage is its off-on, instant-heat feature.[41] Its biggest limitation is that its high heat could detroy small components.[42]

To transfer heat effectively from the soldering iron to a wire or connection, always keep the tip clean and "tin" it at regular intervals. If you let any dirt or burned flux collect on it, this will greatly reduce the amount of heat that it can transfer to the connection. To make consistently good connections, you should clean the tip each time you pick up the iron to use it.[44] Tin the tip regularly by thoroughly cleaning it and then coating it with a layer of solder. This will minimize the formation of oxide on the tip.[45]

Actually, soldering is a fairly simple process. With a little bit of practice, you should be able to make consistently good solder connections and complete each one in only 3 or 4 seconds. The soldering process is described here in the following four steps:[51]

1. Wipe the tip of the iron clean.
2. Place the tip against both the lead and the terminal (or foil).
3. Apply the solder, at the other side of the connection, to the junction point of the lead and the terminal (or foil).
4. Leave the tip on the connection only long enough to thoroughly melt the solder.

A good solder joint always looks smooth and shiny.[53] A "cold" (bad) solder joint will look dull, grainy, or crumbly. The principal causes of cold solder joints are insufficient heat and the movement of a lead during cooling.[52] Insufficient heat, or too much solder, can also cause a rosin solder joint; one where the rosin remains in a connection and acts as an insulator.

Solder bridges are another common soldering problem.[57] These bridges are especially easy to create between close-together foils on a circuit board or between close-together pins on a socket. To avoid solder bridges, use a small tip and thin solder.[58, 27]

Excessive heat can also create problems. Too much heat can damage semiconductors, insulation on wires, and circuit board foils. Always use just enough heat to ensure a good connection and no more.[54]

From time to time in electronics it is also necessary to remove the solder from a connection and to disconnect the wires - to "unsolder" it. The unsoldering (or "desoldering") methods that are most often used on the average workbench use either a simple vacuum bulb or flux-coated braid.[64]

Now proceed to the "Final Examination." Complete this Examination and write in all the answers, even if it seems unnecessary; this will give you one more last reinforcement of what you have learned in this self-instruction Manual.

FINAL EXAMINATION

Answer each of the following questions to see if you have learned all of the information about soldering this book set out to teach you (see "Objectives," Page 6). This examination will give you a complete review of the entire course and is another learning activity designed to help you. After you complete the questions, check your answers against those given in the "Examination Answers." Reread the information in the correct Frames for any question you may happen to get incorrect.

1. The basic purpose of soldering, in electronic equipment, is to provide a good ____________ ____________ that is also ____________ ____________.

2. The process in which solder molecules mix in with the molecules of the metal being soldered is called ____________.

3. Solder is used to join electronic parts because it:

   A. Produces a smooth, shiny connection.
   B. Is not too expensive to produce.
   C. Melts at a lower temperature than other metals.
   D. Is an excellent bonding agent.

4. The melting temperature of solder is determined by its ________/________ ____________.

5. ________/________ solder is the most commonly used grade of solder for electronic work.

6. Flux is used to remove surface ________ from a metal piece before it is soldered.

7. You must use ________-________ solder for electronic work because, after it cools, it is ______________.

8. Use a __________ soldering iron to solder large connections; but use a ____________ ___________ to solder small components to a circuit board.

9. An electrical characteristic called ___________ tells you how much heat a soldering iron will produce.

10. To solder transistors and diodes on a circuit board, you should use a ____.

    A. 75-watt iron.
    B. 25-35 watt iron.
    C. 150-watt iron.
    D. 10-watt iron.

11. The principal advantage that a soldering gun can offer you is its ______-______ __________ _______ feature.

12. What is the principal disadvantage of a soldering gun?

    ____

13. Always clean your soldering iron tip_____________________.

    A. At the beginning of each work day.
    B. At the beginning of each work week.
    C. Whenever it starts to look dirty.
    D. Each time you pick it up to use it.

14. Be sure that you ______ the tip of your soldering iron at regular intervals to minimize _________________.

15. List the following solder steps in their proper order.

    ___ Leave the tip on the connection only long enough to thoroughly melt the solder.

    ___ Apply the solder, at the other side of the connection, to the junction point of the lead and terminal (or foil).

    ___ Wipe the tip of the iron clean.

    ___ Place the tip against the lead and the terminal (or foil).

16. Cold solder joints are caused by:

A. ____.

B. ____.

17. A good solder joint should look ____________ and ____________.

18. If you use a soldering iron with too much heat, you can damage:

A. ______________________________.

B. ______________________________.

C. ______________________________.

19. Most rosin solder joints are caused by either ________________ ____ or ______________________________.

20. A ______________ ______________ is a common soldering error that sometimes creates an accidental connection between two adjacent foils on a circuit board.

21. List two ways to avoid solder bridges.

____

____

22. The desoldering methods that are most often used on the average workbench are:

A. ____

B. ____

EXAMINATION ANSWERS

1. Electrical connection, strong physically.
2. Wetting.
3. (C) Melts at a lower temperature than other metals.
4. Tin/lead ratio.
5. 60/40.
6. Oxide.
7. Rosin - core, noncorrosive.
8. Large, pencil iron.
9. Wattage.
10. (B) 25-35 watt iron.
11. Off-on, instant heat.
12. Its high heat could destroy a small component.
13. (D) Each time you pick it up to use it.
14. Tin, oxidation.
15. (1) Wipe the tip . . .
    (2) Place the tip against . .
    (3) Apply the solder . . .
    (4) Leave the tip on . . .

16. A. Movement of a lead.
    B. Insufficient heat.

17. Smooth, shiny.

18. Semiconductors, insulation on wires, circuit board foils.

19. Too much solder, insufficient heat.

20. Solder bridge.

21. Use a small tip.
    Use thin solder.

22. A. A simple vacuum bulb.
    B. Flux-coated braid.

Good work! Congratulations on completing this Self-Instruction Soldering course. Now that you are finished you probably know more about soldering than a lot of people who have been soldering for years. But remember that this information can only be useful to you if you apply it. Soldering is a skill that requires experience and practice. Therefore, make every effort to do some soldering as soon as possible. By applying what you have learned and practicing, you will become proficient more quickly.

GLOSSARY — INDEX

This section of your Soldering Instruction Manual gives a definition of each listed item (Glossary) and it tells where there is more information (Index) on that subject. The numbers in parentheses tell you where to look for additional information. (F10, F11), for example, would tell you to look at Frame 10 and 11. (P14) would tell you to look at Page 14.

Acid flux (F28, F29): Does an excellent job of cleaning metals to remove surface oxidation; but it is highly corrosive. Never use it for electrical or or electronic soldering.

Alloy (F8, F9): A mixture of two or more different elements, where at least one is a metal. Solder is an alloy of tin and lead.

Applying solder (F51): Always apply the solder at the other side of the connection from where you have placed the tip, at the junction point of the lead and terminal (or foil). This ensures that you heat the connection properly, and not just the solder alone.

Battery-powered irons (F43): These small, portable irons are handy for emergency repairs where line voltage is not available, but they are not recommended for other types of soldering because their batteries run down rapidly and need recharging.

Circuit boards, damage to (F34, P28): Circuit boards can stand soldering level temperatures for a short while, but excessive heat will cause the copper foils to peel off the board

Cleaning the tip (F44): To make consistently good solder connections, you should clean the tip of your soldering iron each time you pick it up to use it. This will keep burnt rosin and other kinds of dirt from building up on it and keeping the heat from getting to the connection.

Cold solder joint (F49, F50, F52): A cold solder joint is a solder connection that did not cure properly, usually because a lead was moved or because not enough heat was applied to the connection. This kind of a connection usually looks dull, crumbly, and crystalline.

Components (P9): This is the general term given to (usually small) electronic parts like transistors, resistors, capacitors, diodes, integrated circuits (etc.).

Diodes, damage to (F34): Too much heat can destroy a diode. Always use a small iron for small components. A 25 to 35-watt iron is usually ideal for most purposes.

Eutectic composition (F24): This is the tin-lead alloy that has the lowest possible melting temperature (361°F.), also called "eutectic solder." It also has no plastic state and, therefore, goes directly from the liquid state to the solid state. This means that it cools and hardens very rapidly. Eutectic solder has a 63-37 tin-lead ratio. 60/40 solder is used in electronics most commonly because it comes very close to this eutectic state.

Eutectic solder (F24): See "Eutectic composition."

Excessive heat (F54): Too much heat can ruin a circuit board foil, burn the insulation on a wire, or destroy a semiconductor such as a transistor, diode, or integrated circuit. Always use a small (25-35 watts) iron to be on the safe side, except for large lugs and wires, and try never to heat any connection for more than 10 seconds.

Flux (F26, F27, F28): A substance that is used to remove the surface oxide from a metal piece before it is soldered. Most of the solder used in electronics has flux built right into it. Always use rosin-core solder for any kind of electronic or electrical work.

Flux-coated braid (F62, F63): A very effective means of removing solder from a connection. Place the braid over the connection, heat it with the iron, and the solder will be drawn up into it as water is drawn into a sponge.

Frames (P6): The instructional material on soldering in this Manual is presented in brief discussions called "Frames," that are numbered and given in numerical sequence.

Heating element (F37): The part of a soldering iron that supplies the heat. Normally, this is a coil mounted in the handle.

Holders (F47): Metal trays used to hold the hot soldering iron while you are not using it.

Insufficient heat (F52, F55): This is one of the most common causes of cold solder joints. The iron does not completely melt the solder, so the solder does not bond properly to the wires and terminal (or foil). Insufficient heat can also cause a rosin solder joint, where the rosin does not get completely boiled away and remains in the connection as an insulation between the parts.

Interface (F6): The area where solder meets the surface of the metal being soldered. This is where "wetting" occurs, where the molecules of solder combine with those of the other metal to form a good mechanical and electrical bond.

Iron-clad tips (F37, F45): Soldering iron tips are made out of copper, but they are often plated with a coating of iron to reduce the effects of oxidation and to help keep it clean. Many of these tips also have a gold or silver plating. These are also called "plated tips."

Jumper wire (P70): A small wire that is connected from one place to another on a circuit board.

Melting point (F15, F16, F31): The particular temperature at which a given tin-lead alloy (solder) melts. The 60/40 solder that is used most commonly in electronic and electrical work has a melting point of 370°F.

Melting temperature: See "Melting point."

Movement of leads (F52): Always be sure that the leads do not move while a solder connection is cooling. Even the slightest movement at this time can cause a cold solder joint. Let the solder harden naturally for several seconds.

Oxidation, oxide (F25, F45): Most metals, when exposed to the air, have an insulating layer of oxide form on their surface. This oxide prevents solder from adhering to the metal. It is removed from the metal surfaces by the flux. You should also minimize oxidation on soldering tips by covering them at regular intervals with a coating of solder.

Pencil irons (F32, F33, F34, F39, F43): A 25 to 35-watt pencil iron will work very well for almost all electronic soldering jobs. Some of these pencil irons are available with removeable heating elements and with removeable tips for various types of applications. Variable heat pencil irons are also available for use with larger and smaller soldering jobs.

Plastic state (F20): A semi-liquid state in which the solder can be molded or moved to some degree, but is not liquid enough to actually run or flow.

Plated tip (F37, F45): See "Iron-clad tip."

Portable soldering irons (F43): See "Battery-powered irons."

Rosin core solder (F18, F28): The most common type of solder used in electronics, usually described as "60/40 rosin core solder." The rosin flux is noncorrosive. Therefore, if any should remain on the outside of the connection after the solder has hardened, it will not do any harm.

Rosin flux (F28): See "Rosin core solder," above.

Rosin solder joint (F55, F56): A solder joint where the rosin flux was not all boiled away during the soldering process. The remaining rosin, in these cases, acts as an insulator between the conductors. Rosin solder joints are caused by insufficient heat and by too much solder.

Semiconductors, damage to (F34, F54): Too much heat can destroy a semiconductor (diode, transistor, integrated circuit). Always use a small soldering iron for small components, a 25 to 35-watt pencil iron is ideal for most purposes. Try not to heat any solder connection for more than about 10 seconds.

Solder Wick (P64, P73): This is the trademark name for the flux-coated braid produced by the Solder Removal Company.

Solder (F1, F5, F8): A tin/lead alloy that melts at a very low temperature, making it ideal for the joining together of other metals. Melted solder is flowed over the other metals; and when it cools, it produces an excellent electrical connection that is also strong physically.

Solder bridge (F57, F58): An accidental solder connection between two close-together lugs or pins, or between close-together foils on a circuit board. Avoid solder bridges around close-together work by using an iron with a small tip and thin solder. To eliminate a solder bridge, use any of the unsoldering methods; or hold the solder bridge above the iron so that, when it is heated, the solder will flow down onto the tip of the iron.

Soldering (F1, F7): The process of bonding together two or more metals by applying a tin/lead alloy to them. This is the best way there is to join electrical and electronic parts.

Soldering gun (F32, F39, F40, F41): A soldering iron in the shape of a gun. The principal advantage of a soldering gun is its on-off, instant heating capability. Its principal disadvantage is that its high heat level could destroy a small component.

Soldering iron (F31, F32, F37): A commonly used tool for applying solder to an electrical connection. Its principal parts are: the tip, the heating element, the handle, and the AC line cord.

Tack soldering (P71): A solder connection where the wire or lead does not have any mechanical support. It is absolutely essential to hold the wire absolutely still any time you make a tack-soldered connection.

Tin/lead ratio(F9, F15, F16, F24): The overall characteristics of solder, especially the melting temperature, depend heavily on the ratio of tin and lead that was used to produce it. A 60/40 ratio, 60% tin and 40% lead, is used in the grade of solder most commonly used in electronics.

Tinning the tip (F45, F46): The process of applying a layer of solder to the tip of a soldering iron. This layer of solder minimizes the formation of oxide on the tip. The oxide layer would greatly reduce the amount of heat that could be transferred to the connection.

Tip (F31, F33, F37, F39, F46): The part of the soldering iron that comes in contact with the connection. Usually it is a copper rod that is pointed or chisel-shaped at one end. Many tips are iron-clad, and have a gold or silver plating to reduce the effects of oxidation, to extend its life, and to improve heat transfer. Soldering iron tips are usually replaceable.

Unsoldering (F59 to F64): The process of removing solder from a connection so you can disconnect a wire. On the average workbench, most unsoldering is done with a simple vacuum bulb or with flux-coated braid. Also called "desoldering."

Vacuum bulb (F60): A small vacuum bulb with a heat-insensitive tip that is used for desoldering. To use it, you heat the solder and place the tip against it. Then you squeeze and release the bulb.

Vacuum desoldering (F60, F61): Any of the desoldering methods that use a vacuum to remove the solder. This could be a simple vacuum bulb like the one described above, or something more elaborate like a solder sucker.

Wattage (F34): An electrical characteristic that tells you how much heat a soldering iron will produce. Soldering irons for both general work and electronic work range from about 10 watts to about 250 watts. A 25 to 35-watt pencil iron is ideal for most electronic soldering.

Wetting (F6): In any properly made connection, the molecules of solder mix with those on the surface of the metal being soldered. This is called "wetting." The solder actually imbeds itself into the surface of the metal.

CUSTOMER SERVICE

REPLACEMENT PARTS

Please provide complete information when you request replacements from either the factory or Heath Electronic Centers. Be certain to include the **HEATH** part number exactly as it appears in the parts list.

Replacement parts are maintained specifically to repair Heath products. Parts sales for other reasons will be declined.

ORDERING FROM THE FACTORY

Print all of the information requested on the parts order form furnished with this product and mail it to Heath. For telephone orders (parts only) dial 616 982-3571. If you are unable to locate an order form, write us a letter or card including:

- Heath part number.
- Model number.
- Date of purchase.
- Location purchased or invoice number.
- Nature of defect.
- Your payment or authorization for COD shipment of parts not covered by warranty.

Mail letters to: Heath Company
Benton Harbor, MI 49022
Attn: Parts Replacement

Retain original parts until you receive replacements. Parts that should be returned to the factory will be listed on your packing slip.

OBTAINING REPLACEMENTS FROM HEATH ELECTRONIC CENTERS

For your convenience, "over the counter" replacement parts are available from the Heath Electronic Centers listed in your catalog. Be sure to bring in the original part and purchase invoice when you request a warranty replacement from a Heath Electronic Center.

TECHNICAL CONSULTATION

Need help with your kit?—Self-Service?—Construction?—Operation?—Call or write for assistance. You'll find our Technical Consultants eager to help with just about any technical problem except "customizing" for unique applications.

The effectiveness of our consultation service depends on the information you furnish. Be sure to tell us:

- The Model number and Series number from the blue and white label.
- The date of purchase.
- An exact description of the difficulty.
- Everything you have done in attempting to correct the problem

Also include any other information you think might be helpful.

Please do not send parts for testing, unless this is specifically requested by our Consultants.

Hints: Telephone traffic is lightest at midweek — please be sure your Manual and notes are on hand when you call.

Heathkit Electronic Center facilities are also available for telephone "walk-in" personal assistance.

FOR PARTS REQUESTS ONLY

- Be sure to follow instructions carefully.
- Use a separate letter for all correspondence.
- Please allow 10 - 14 days for mail delivery time.

DO NOT WRITE IN THIS SPACE

INSTRUCTIONS

- Please print all information requested.
- Be sure you list the correct **HEATH** part number exactly as it appears in the parts list.
- If you wish to prepay your order, mail this card and your payment in an envelope. Be sure to include 10% (25¢ minimum, $3.50 maximum) for insurance, shipping and handling. Michigan residents add 4% tax.

Total enclosed $________

- If you prefer COD shipment, check the COD box and mail this form. COD ☐

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CITY ____________________

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Model # ________ Invoice # ________

Date Purchased ________ Location Purchased ________

LIST **HEATH** PART NUMBER	QTY.	PRICE EACH	TOTAL PRICE

TOTAL FOR PARTS	
HANDLING AND SHIPPING	
MICHIGAN RESIDENTS ADD 4% TAX	
TOTAL AMOUNT OF ORDER	

SEND TO: **HEATH COMPANY**
BENTON HARBOR
MICHIGAN 49022
ATTN: PARTS REPLACEMENT

Phone (Replacement parts only): 616 982-3571

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